6F18

44-33

DC DIGITAL VOLTMETER

MODEL 3600

Serial Nos. Through

Federal Stock No.

Contract No. DAAH01-70-C-1202

SINGER

TELE-SIGNAL

250 CROSSWAYS PARK DRIVE
WOODBURY, LONG ISLAND, NEW YORK 11797
516/921-9400 • TELEX 961468

PRELIMINARY

INSTRUCTION MANUAL

DC DIGITAL VOLTMETER

MODEL 3600

Serial Nos. Through

Federal Stock No.

Contract No. DAAH01-70-C-1202

Maintenance forms, records and reports which are to be used by maintenance personnel at all maintenance levels are listed in and provided by TM 38-750.

SINGER

TELE-SIGNAL

250 Crossways Park Drive, Woodbury, L.I., New York 11797

15 May 1971

TABLE OF CONTENTS

Paragraph		Page
	SECTION I - INTRODUCTION	
1-1	Scope of Manual	1-1
1-4	Purpose and Use of Equipment	1-1
1-7	Accessories and Options	1-2
1-9	General Description	1-3
1-12	Specifications	1-4
	SECTION II - OPERATION	
2-1	General	2-1
2-3	Preparation for Use	2-1
2-4	Inspection	2-1
2-5	Mounting	2-1
2-12	Application of Power	2-7
2-14	Operating Controls, Indicators, and Connectors	2-7
2-16	Operating Procedures	2-9
2-17	Local Operation	2-9
2-18	Modular Interface Operation	2-10
2-19	Remote Operation	2-11
2-20	Packaging	2-11
	SECTION III - THEORY OF OPERATION	
3-1	Block Diagram Analysis	3-1
3-2	General	3-1
3-4	Function and Control Section	3-1
3-5	Analog-to-Digital Converter Section	3-3
3-13	Power Supplies	3-7
3-14	Modular Interface Mode	3-8
3-16	Calibration Mode	3-8
3-17	Remote Program Mode	3-9
3-18	BCD Outputs	3-9
3-19	Theory of Operation, Function and Control Section	3-10
3-20	Range/Mode Control	3-10
3-25	Scaling Amplifier	3-11
3-26	+1.000V Calibrator	3-12
3-27	Power Supplies	3-12
3-29	Theory of Operation, Analog-to-Digital Converter Section	3-13
3-30	Active Filter Circuit	3-13
3-31	Input Amplifier Circuit	3-13
3-33	Integrator Circuit	3-14
3-34	Reference Amplifier Circuit	3-14
3-35	Comparator and Control Circuits	3-15
3-39	Read Rate Control Circuit	3-17
3-40	Clock and Count Inhibit Gate	3-18
3-41	Decade Counter	3-19
3-42	Storage Register and Display	3-19
3-43	Polarity Detector Circuit	3-21
3-44	Power Supplies	3-22

TABLE OF CONTENTS (Cont)

Paragraph		Page
	SECTION IV - MAINTENANCE	
4-1	General	4-1
4-3	Test Equipment Required	4-1
4-5	Performance Standards	4-1
4-7	Trouble Localization	4-8
4-11	Adjustments and Test Points	4-14
4-13	Analog-to-Digital Converter Test	4-14
4-15	Calibration	4-17
4-16	Basic DVM	4-17
4-17	Calibration Option	4-20
4-18	Analog-to-Digital Converter Removal	4-21
4-20	Voltage Data	4-21
	SECTION V - SCHEMATIC DIAGRAMS	
	SECTION VI - PARTS LIST	

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Model 3600 Digital Voltmeter	1-0
2-1	Rack Installation Outline Dimensions	2-2
2-2	Module Interface (Option 3) Connector J3 Wiring	2-4
2-3	Remote Programming/BCD (Options 1 and 2) Connector J4 Wiring	2-5
2-4	Operating Controls, Indicators and Connectors	2-8
2-5	Typical Packaging Diagram	2-12
3-1	Model 3600 DC DVM, Functional Block Diagram	3-2
3-2	Minus Ten Digit Gate Waveforms	3-20
4-1	Chassis and Main Circuit Board (A1), Adjustments and Test Points	4-15
4-2	Analog-to-Digital Converter, Adjustments	4-18
5-1	Model 3600 DC DVM, Function and Control (A1), Schematic Diagram	5-2
5-2	Model 3600 DC DVM, Power Supplies and Option Connectors (A1), Schematic Diagram	5-3
5-3	Model 3600 DC DVM, Analog Board (A2), Schematic Diagram	5-4
5-4	Model 3600 DC DVM, Digital Board (A3), Schematic Diagram	5-5

LIST OF TABLES

Number		Page
1-1	Model 3600 DC DVM Options	1-4
1-2	Specifications	1-4
2-1	Operating Controls, Indicators and Connectors	2-13
4-1	Test Equipment Required	4-1
4-2	Performance Standards Checks	4-3
4-4	Function and Control Section Voltage Data	4-22
4-5	Analog-to-Digital Converter Section Voltage Data	4-23

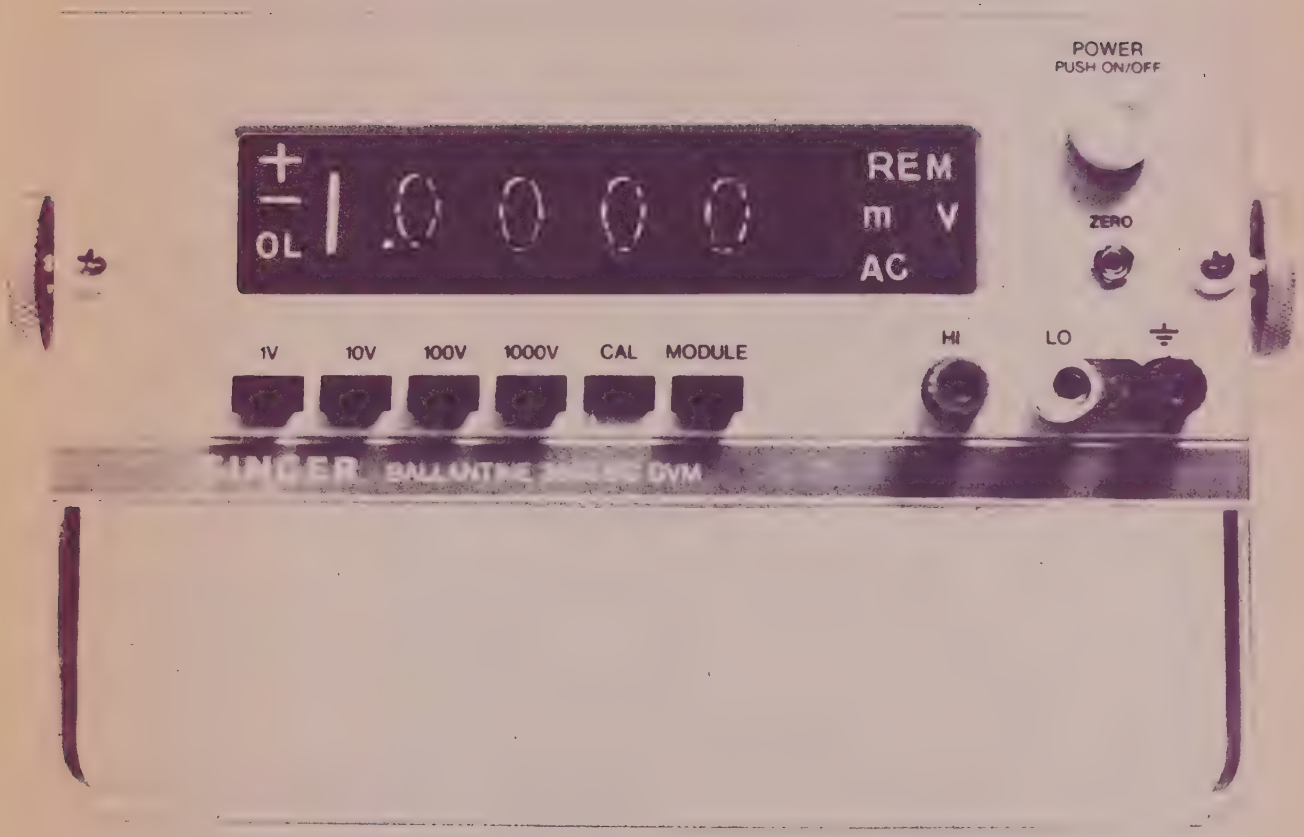


Figure 1-.. [illegible] Digital Voltmeter

SECTION I

INTRODUCTION

1-1. SCOPE OF MANUAL.

1-2. This manual provides operating and maintenance instructions for the Model 3600 DC Digital Voltmeter, hereafter referred to as the DVM, manufactured by The Singer Company. This manual also includes general information, installation, theory of operation, maintenance data, schematic diagrams, and a repair parts list. The DVM is illustrated in figure 1-1.

1-3. The information contained in this manual refers to the standard version of the DVM and is current only to date of publication. Differences in equipment components, specifications, and performance resulting from the Singer Company's continuous product improvement program or customer design and application requirements are described in addendum sheets.

1-4. PURPOSE AND USE OF EQUIPMENT.

1-5. The DVM is a highly accurate bench instrument that permits rapid, high resolution measurements of direct current voltages from 100 uV to 1000V with an unambiguous full 4-digit readout plus a 1-digit overrange. A 100% overrange is featured on all scales except 1000V, which is 50%. Basic instrument accuracy is ±0.01% of reading plus ±0.01% of F.S. on all ranges. The DVM also features automatic polarity switching, high input impedance, and high common and normal mode rejection ratios. The basic unit becomes an excellent systems DVM with the inclusion of several options, see table 1-1, as follows:

[illegible] number of converter modules. When used with [illegible] 3573 or 3573M True RMS Module, RMS voltages from 10 Hz [illegible] over a range of 1 mV to 1000V (full scale) can be measured with high accuracy.

b. Remote Programming. With this option, the DVM can be programmed remotely for range and function. It is especially adaptable for use in programmed checkout systems.

c. BCD Outputs. The BCD outputs option provides 1-2-4-8 positive, DTL and TTL compatible signals for use in programmed checkout systems where remote or automatic evaluation or data printout is required.

d. Internal Calibration. A highly accurate, internal calibration voltage is provided with this option.

1-6. Typical applications of the DVM include the following:

a. Bench or systems DC measurements and testing.

b. Engineering design.

c. Production testing.

d. Programmed systems checkouts (with appropriate options).

e. Wideband, sensitive AC measurements to 11 MHz (with modular interface option and coupled with Model 3573M True RMS AC Module).

1-7. ACCESSORIES AND OPTIONS.

1-8. Options that may be added to the basic DVM are listed in table 1-1. All options require factory installation. Kits for combining the DVM with a module are also listed in table 1-1.

1-9. GENERAL DESCRIPTION.

1-10. The DVM is a dual-slope, integrating-type digital voltmeter which accepts DC signals in the voltage range from 100 uV to 1000V. The instrument functions as a voltage-to-time converter. A capacitor (integrator) is charged by the input voltage for a known length of time, and then discharged to its original state by a known reference voltage. The time required to discharge the capacitor is directly proportional to the input voltage. This period is measured very accurately using a digital counter and displayed with a 4-digit readout plus a 1-digit overrange. The instrument is comprised of two discrete sections. The function and control section controls power, input ranging and attenuation, remote control functions and processes the input voltages for measurement. The analog-to-digital converter section accepts scaled analog input voltages and displays them as a four digit numeral readout.

1-11. All circuits are solid-state and mounted on three easily accessible printed circuit boards, a main (mother) circuit board (see figure 4-1) and a two-board sandwich arrangement. The entire function and control section of the DVM, located on the main circuit board, on the front or rear panel, or on the main chassis of the instrument, is designated with an A1 prefix. The sandwich boards are designated with the prefix A2 and A3; A2 is the analog circuit board of the converter, A3 the digital circuit board. The unit may be rack-mounted or operated as a portable instrument described in Section II.

1-12. SPECIFICATIONS.

1-13. The electrical and physical characteristics of the DVM are listed in table 1-2.

Table 1-1. Model 3600 DC DVM Options

OPTION OR ACCESSORY	OPTION NO. OR MODEL	PURPOSE
Remote Programming	1	Enables remote programming of range and function.
BCD Outputs	2	Provides 1-2-4-8 positive, DTL and TTL compatible outputs.
Modular Interface	3	Enables DVM to accept inputs from converter modules.
Internal Calibration	4	Provides highly accurate internal calibration voltage.
Rack-Mounting Kit	801	Contains locking strips, handles and brackets for rack mounting Model 3600 DVM with other modules.
Portable Mounting Kit	802	Same as Kit 801 except it has bail for bench (portable) mounting.

Table 1-2. Specifications

PARAMETER	SPECIFICATION
Ranges	1, 10, 100, 1000 VDC Full Scale
Overrange	100% all ranges, except 50% on 1000V range
Accuracy at 23°C:	±0.01% of reading, ±0.01% of full scale range ±1 digit

Table 1-2. Specifications (Cont)

PARAMETER	SPECIFICATION
Ranging	Manual, front panel pushbuttons--Remote with Option 1
Polarity	Automatic with (+) or (-) indication
CMRR	$>$ 100 dB from DC to 60 Hz
NMRR	$>$ 60 dB at 60 Hz
Input Impedance	10 megohms all ranges
Integrating Time	33.2 MS
Reading Rate	Nominal 4/sec (20/sec, 30/sec available)
Temperature Range	0 to 50° C
Temperature Coefficient	$\pm$0.0015% F.S. +0.0015% reading/°C
Humidity	Specified accuracy to 60%R.H.
Stability	
24-hour	$\pm$0.01% F.S. $\pm$0.01% of reading
3-month	$\pm$0.02% F.S. $\pm$0.02% of reading
Warm-Up Time	30 minutes
Remote Programming (Option No. 1)	
Type	Contact closures to ground--sink 5 mA max.
Logic	Negative-True $\leq$ +1V, False $>$ +4V, or open, DTL/TTL compatible
BCD Outputs (Option No. 2)	
Type	4 line 1-2-4-8 for each digit.
Logic	Positive--True $\geq$ +3.5V, False $<$ +0.5V, DTL/TTL compatible
Modular Interface (Option No. 3)	
Range and Function	Automatic polarity
Logic	Negative--True $<$ +1V, False $\geq$ +4V, or open, DTL/TTL compatible

Table 1-2. Specifications (Cont)

PARAMETER	SPECIFICATION
Internal Calibration (Option No. 4)	
Type	Manual, front panel pushbutton
Voltage	1.0000 volt
Accuracy	±0.01%
Stability	±0.01% for 90 days at 23°C ±2°
Power Requirements	
Line voltage	115/230 volts ±10%
Line frequency	50 to 400 Hz
Power consumption	7 watts
Dimensions	3.5" H x 8.5" W x 12" D
Weight	7.5 lb

SECTION II

OPERATION

2-1. GENERAL.

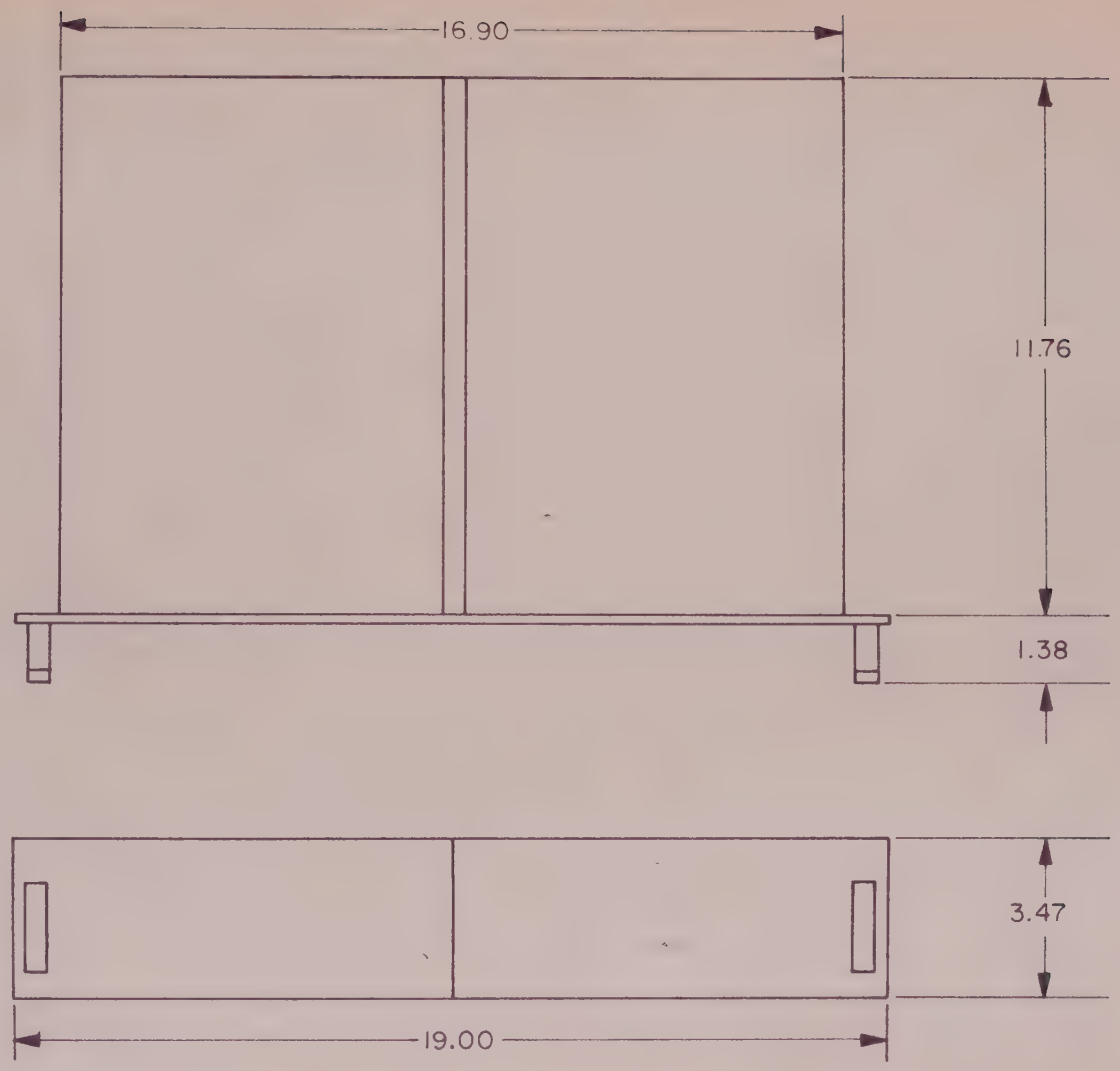
2-2. This section contains installation and operating instructions for the DVM. The instrument has been factory tested and adjusted and is shipped in a ready-to-operate condition. However, no attempt should be made to install or operate the DVM until thorough familiarity with the contents of this section has been achieved.

2-3. PREPARATION FOR USE.

2-4. INSPECTION. After unpacking the DVM, inspect it for indications of damage which may have occurred during shipment. Check the pushbutton switches for positive action and ease of operation.

2-5. MOUNTING. The DVM may be operated as a portable or a rack-mounted unit either singly or combined with a converter such as the Model 3573M True RMS AC Module (Option 3). As a single portable instrument, the loop handle may be used to tilt it to a convenient operating and reading position. Outline dimensions for rack mounting are given in figure 2-1.

2-6. Rack-Mounting Kit 801 or Portable Mounting Kit 802 is required to join the DVM with a module into a single, compact package. For rack mounting, the rack handles must be used (Kit 801). The portable configuration requires the loop handle (Kit 802) which may also be used to tilt the instrument to a convenient reading position.


16.90
11.76
1.38
3.47
19.00

To combine two modules mechanically, place them in the desired attitude and slide on the combining bars, one at a time, with the set screws toward the front panels. Tighten the set screws, but not more than is necessary to hold the units firmly together.

2-7. The rack handles mount with three flat-head screws at the front of the outer side panels. All hardware is supplied with the combining kits. The portable handle mounts in the threaded holes exposed through the side covers. If the handle is to be used as a bail to tilt the instrument, be certain to tighten the thumbscrews firmly against their friction washers. If the handle is to be used to tilt the instrument up at the rear, mount the combining bars with their set screws at the rear.

2-8. Electrical interface between the DVM and a converter module (Option 3) is made through MODULE Interface Connector J3, a 24-pin connector. (See Figure 2-2.) An interconnecting cable is supplied with the mounting kit (801 or 802). Although cable ends are identical, the cable connectors mate in only one way with the MODULE connectors on the units. Form the cable into an 'S' when using the over/under mechanical configuration. The connectors are provided with sliding locks which will prevent accidental disconnection. ALWAYS TURN THE INSTRUMENT OFF BEFORE CONNECTING OR DISCONNECTING THE CABLE. Figure 2-2 identifies the interface signals at each active pin of the connector.

2-9. Electrical interface for the remote programming and BCD outputs options are made through BCD connector J4, a 50-pin connector. Figure 2-3 identifies the interface signals at the active

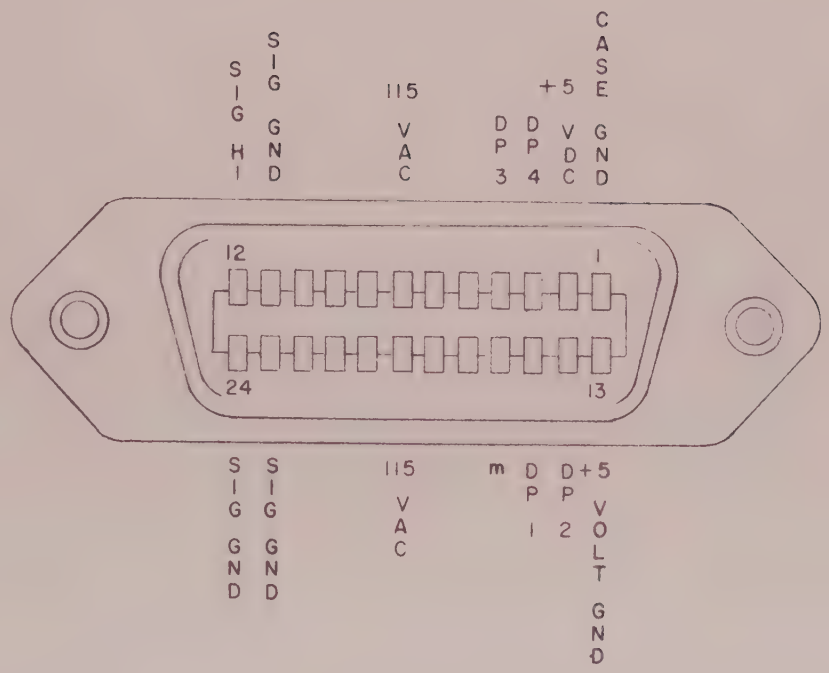


Figure 2-2. Modular Interface (Option 3) Connector J3 Wiring

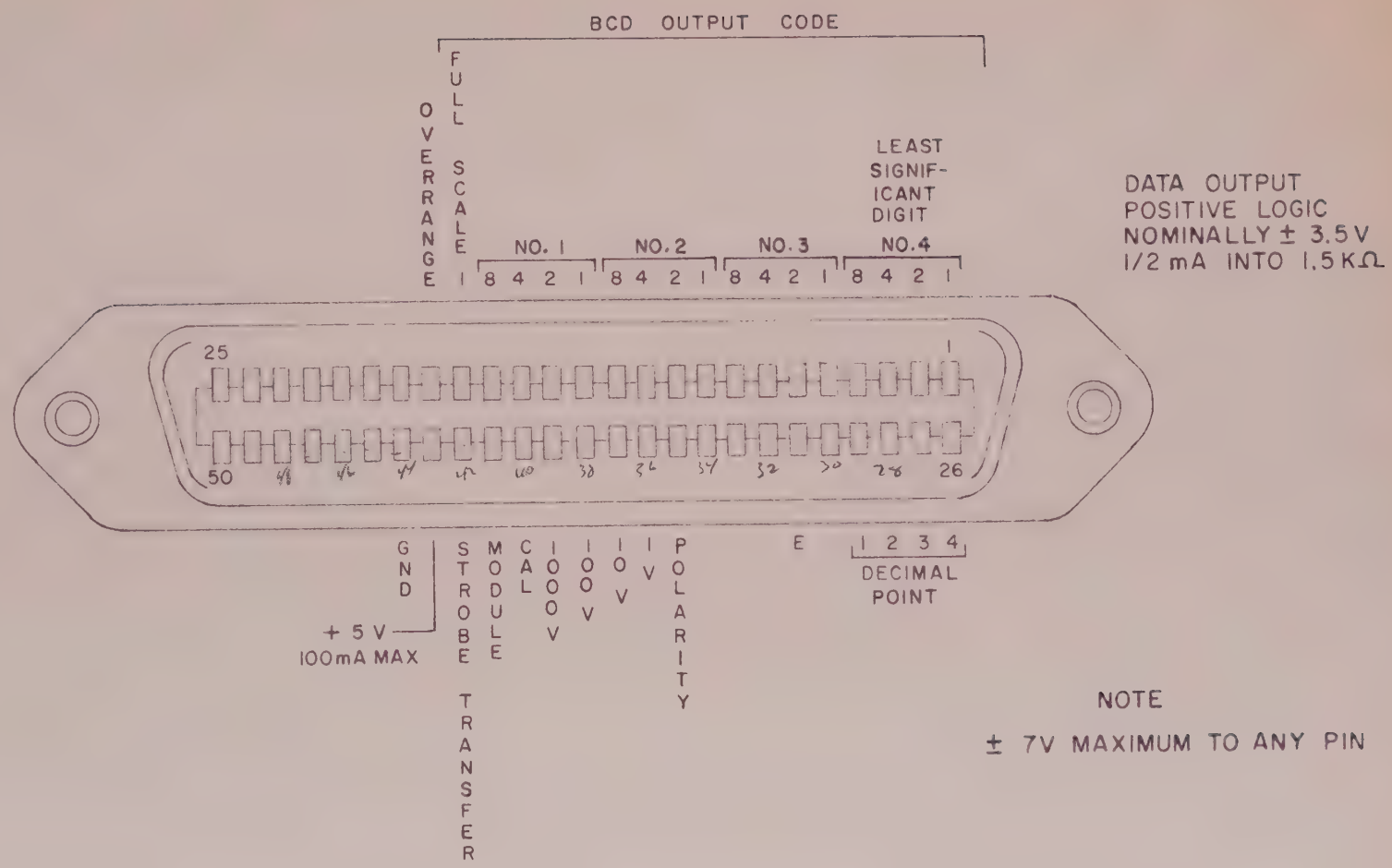


Figure 2-3. Remote Programming/BCD (Options 1 and 2) Connector J4 Wiring

pins of connector J4. All DVM functions, except the application of power, may be remotely controlled by negative logic signals (lows) at the input program lines of this connector. These signals may be supplied from NPN transistors, DTL/TTL gates, or switch closures to system ground. When the appropriate pin on connector J4 is grounded or brought below +1V, that function is selected (true) just as if the front panel controls had been manipulated. When the pin is electrically floating or brought above +4V, that function is not selected (false).

CAUTION

NEVER APPLY MORE THAN ±7 VOLTS TO ANY PIN OF THE BCD OUTPUT CONNECTOR. Higher voltages may damage internal circuits.

2-10. Any circuitry used for programming should be capable of sinking +4 mA minimum for each pin to be grounded. Ideally by returning this current to the ground pin on programming connector J4, the possibility of ground current errors when the DVM is used with a converter to make low-level measurements will be eliminated. However, for convenience, this current can be returned to signal ground provided care is taken to avoid interaction with the measured signal. When the external programming circuit is prone to mechanical switch bounce, or electrical noise above 200 mV peak, by-pass each program wire to ground with a .01 uF disc capacitor. It is best to do this right at the programming pins which mates with J4.

2-11. Data output lines are also provided on the BCD OUTPUT connector. Each character and decimal point is assigned a pin. Each

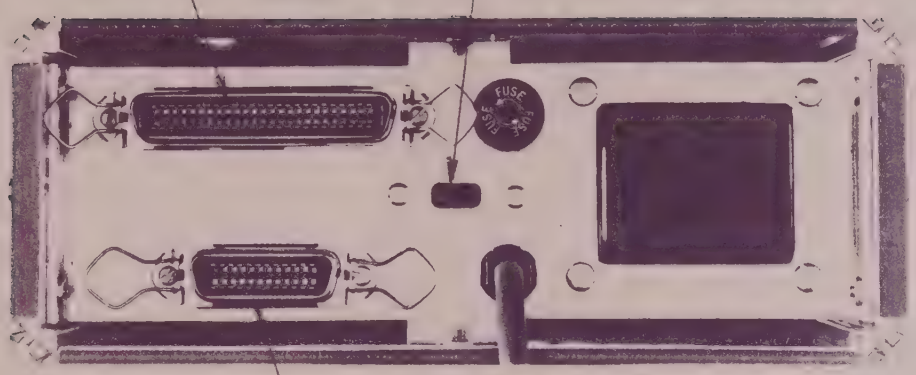
decimal digit of the Nixie display is given in a 4-wire binary code (1248), and each code wire is assigned a pin. All outputs are positive logic with a true level of +3.5V minimum and a false level of +0.5V maximum. Each output can supply a minimum current of 500 ua into a 1500 ohm load (true) and sink a maximum current of 3 mA (false). If higher source or sink currents are required, external buffer circuits should be used. Standard DTL or TTL power gates are suitable. The +5 pin (4;) on J4 may be used to provide power to such circuits up to a maximum total drain of 10[illegible] mA.

2-12. APPLICATION OF POWER.

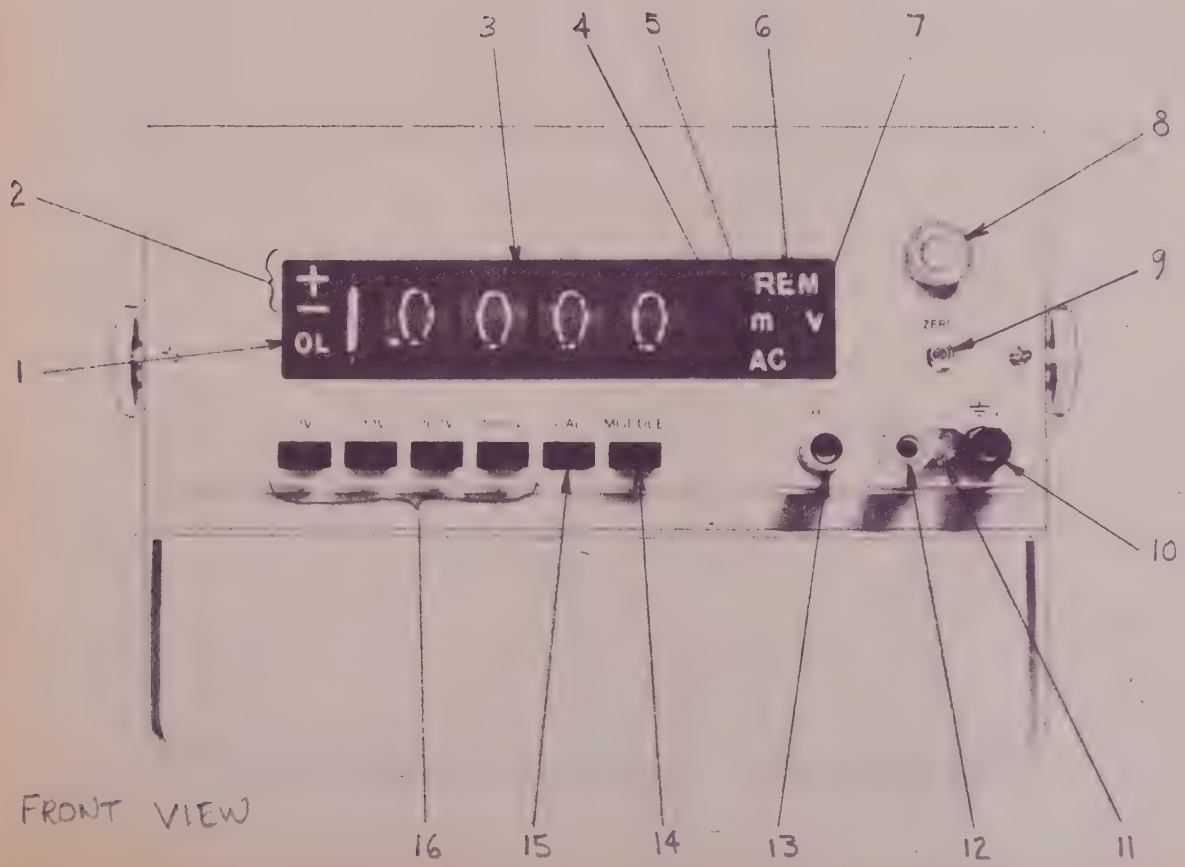
2-13. The DVM is designed to operate from either 115V or 230V, 50 to 400 Hz power. Be sure that the 115V/230V line selector switch (figure 2-4) is at the appropriate position before connecting power to the instrument. Also, check that the line fuse is correct for the power source. A 0.5 A fuse is required for 115V operation. The fuse must be changed to 0.25A for proper protection at 230V input power. Push the POWER switch to energize the DVM. If the DVM has been stored, or not operated for a long period of time, allow it to run at its normal operating temperature for one or two hours. This is particularly true when the instrument is first used after long exposure to a humid storage environment. The instrument should be observed during this initial warmup period to ensure that its operation is normal.

2-14. OPERATING CONTROLS, INDICATORS AND CONNECTORS.

2-15. Table 2-1 lists and describes the function of all operating controls, indicators, and connectors of the DVM that are illustrated in figure 2-4.



REAR VIEW



FRONT VIEW

Figure 2-4. Operating Controls, Indicators, and Connectors

2-17. OPERATING PROCEDURES.

2-17. NORMAL OPERATION. Measurements of DC input voltages from [illegible] are made with simplicity, speed, and accuracy. Proceed as follows:

a. Verify that all pushbuttons are released. Push the POWER push switch to apply power to the instrument. Observe that the POWER indicator illuminates. All Nixies of the display should be illuminated.

NOTE

The DVM is usable within a few seconds after power is applied and will provide measurement accuracy near that specified for the unit. After 30 minute warm-up time, accuracy will be within specifications.

b. Short out the HI and LO input terminals and depress the 1V range pushbutton. The display should read 0.0000. If it does not, adjust the ZERO potentiometer with a screwdriver.

c. If the DVM is equipped with an internal calibration voltage (Option 4), depress the CAL and 1V pushbuttons. The display should be 1.0000 ±1 digit. Refer to calibration if required. Release the CAL and 1V pushbuttons.

d. Connect the voltage to be measured to the HI and LO input terminals. If the voltage is known, depress the appropriate range pushbutton. If the voltage is not known, start with the highest range and decrease the range until four figures are displayed. The V and the + or - polarity indicators will illuminate automatically.

NOTE

Overloading will not harm the DVM, up to 1500VDC. The advantage of proceeding from right to left is that overloading is prevented.

e. To operate the DVM with "floating" input terminals, remove the shorting strap between the LO and ground terminals.

NOTE

With the shorting strap removed, the DVM is completely isolated and shielded from chassis ground. Leakage resistance between the LO terminal and ground is greater than 100 megohms, and capacitance is approximately 1100 pF. The maximum potential that should be permitted between the LO terminal and ground is 100V.

f. A shielded BNC input terminal should be used for low-level measurements and to prevent hum pick-up due to high source resistance.

2-18. MODULAR INTERFACE OPERATION. To operate the DVM in conjunction with a converter module such as the Model 3573M True RMS AC Module, first check the DVM for proper zeroing and 1V calibration as described in paragraph 2-17, steps b. and c., then depress the MODULE pushbutton. The function and ranging of the DVM are automatically controlled by the module. The following will be noted on the DVM:

a. Both the + and - polarity indicators will be extinguished, since AC will be measured.

b. The AC indicator will be illuminated.

c. The m and V indicators will be illuminated depending on the AC range selected. Both m and V (mV) will be illuminated for 1, 10 and 100 millivolt ranges; only the V for 1, 10, 100 and 1000V ranges.

d. The appropriate decimal will be illuminated, depending on the range.

2-19. REMOTE OPERATION. Except for the application of power, remote operation of the DVM is completely automatic, under the control of the remote system. The following will be noted on the DVM:

a. The REM indicator will be illuminated to indicate that programmed remote operation is in progress.

b. Range and mode functions will be controlled by the remote system. The decimal, polarity, AC, m and V indicators will be illuminated as appropriate for the specific test.

c. If a printout function is part of the system, the readout will be printed out as controlled by the program.

2-20. PACKAGING.

2-21. If the DVM is to be stored for a short time, use a suitable protective covering, such as plastic, and store in a clean, dry area. Store accessories and this instruction manual in a carton or bag, and fasten to the equipment to avoid loss. Figure 2-5 illustrates the method of packaging the DVM for long term storage or shipment. Use the original wrappings if these were retained. Otherwise, obtain suitable packaging material and package in accordance with figure 2-5.

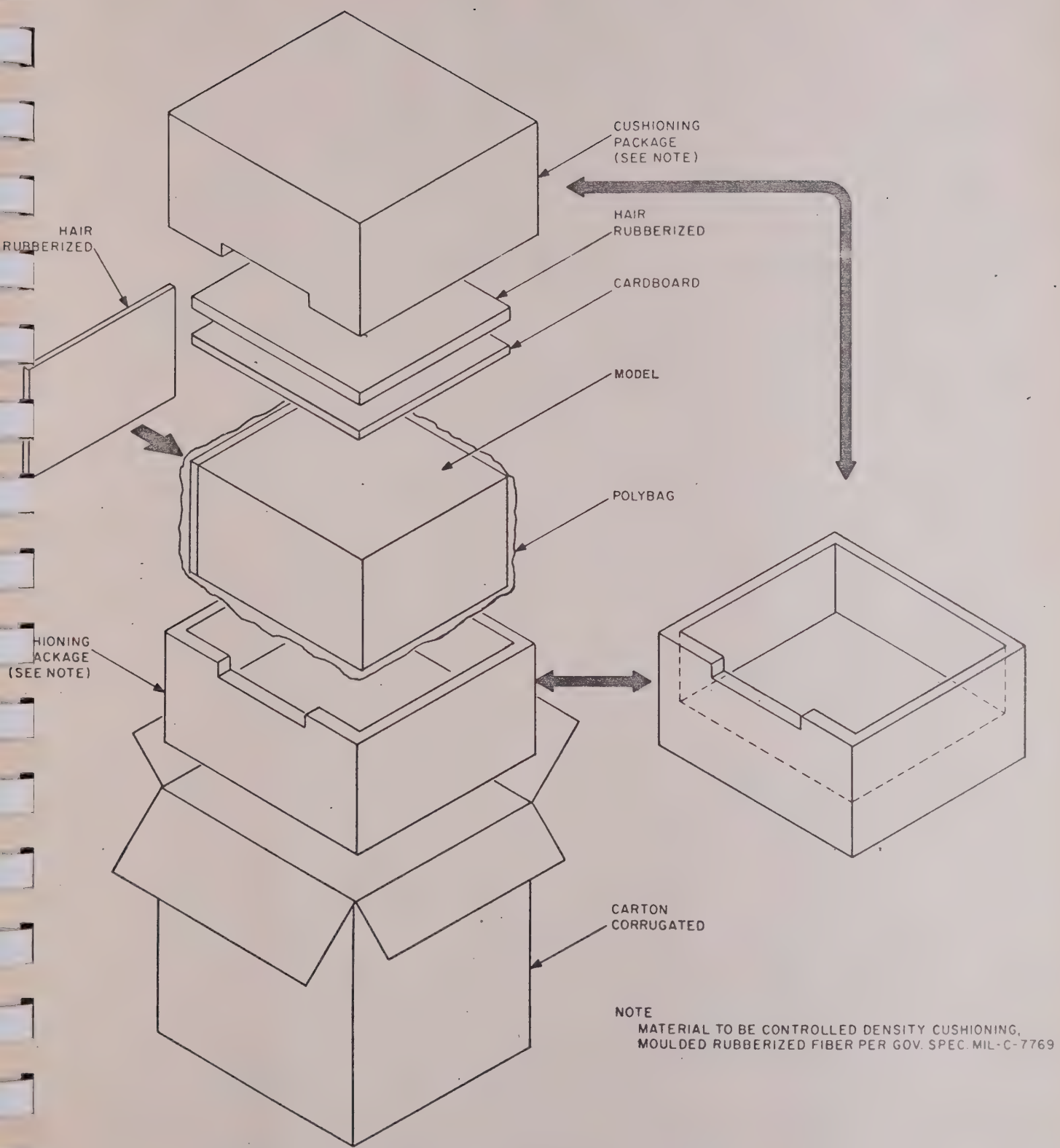


Figure 2-5. Typical Packaging Diagram

Table 2-1. Operating Controls, Indicators and Connectors

CONTROL, INDICATOR OR CONNECTOR	FIGURE 2-4 INDEX NO.	FUNCTION
OL indicator	1	Illuminates when input voltage exceeds selected range.
Polarity (+, -) indicators	2	Indicate polarity of input voltage when illuminated. Both indicators are extinguished for MODULE operation (AC measurements, Option 3).
Digital readout Nixie-type display	3	Four digit plus one overrange display of input voltage. Decimal indicator (between each digit) automatically illuminated for selected range.
AC indicator (DS1)	4	Illuminated for MODULE operation to indicate that AC voltages are being measured.
m indicator (DS2)	5	In MODULE operation, illuminates in mV AC ranges. Operation is controlled by the module.
REM indicator (DS3)	6	Illuminates in remote programming operation (Option 1) under control of remote system.
V indicator (DS4)	7	Illuminates in all DVM ranges of voltage measurements as well as module and remote mode functions. Controlled by remote system in remote programming.
POWER push switch and indicator	8	Applies power to DVM. A "push-push" type switch that disconnects power with a second "push". The built-in indicator illuminates when power is applied.
ZERO adjustment (screwdriver)	9	Adjusts DVM zero at no signal input.

Table 2-1. Operating Controls, Indicators and Connectors

CONTROL, INDICATOR OR CONNECTOR	FIGURE 2-4 INDEX NO.	FUNCTION
Ground terminal (black)	10	Provides connection to chassis ground (normally DC return when jumper is connected).
Ground jumper strap	11	Straps LO input terminal to chassis ground.
HI (red), LO (white), ground (black) input terminals	12, 13	DC voltage input terminals. LO terminal is connected to chassis ground through ground strap (item 11). Input terminals are "floating" when strap is disconnected.
MODULE pushbutton	14	Functions with modular interface (Option 3). When depressed, DVM accepts input voltages and is controlled by associated module.
CAL pushbutton	15	Functions with internal calibration (Option 4). When depressed, applies an internal 1.0000V calibration signal to the DVM input for evaluation and full scale adjustment.
Range pushbuttons: 1V, 10V, 100V, 1000V	16	Select range for DC voltage measurement.
115V/230V line voltage selector S9	17	Slide switch that connects power supply circuits for operation at 115V or 230V line.
PROGRAMMING BCD output connector J4	18	50-pin connector for input/output interface with remote system (Option 2).
MODULE connector J3	19	24-pin connector for input interface with converter (Option 3).

SECTION III

THEORY OF OPERATION

3-1. BLOCK DIAGRAM ANALYSIS. (See Figure 3-1.)

3-2. GENERAL. The DVM contains two discrete functional sections as shown in figure 3-1. The function and control section contains circuitry that controls input range and mode switching, and scales the voltage under test for measurement in the analog-to-digital converter section. The analog-to-digital converter section accepts the scaled input voltages and converts them to a proportional time interval. The time interval is then very accurately measured with a digital counter and displayed with a 4-digit numeral readout, plus a 1-digit overrange.

3-3. The capability of the basic DVM may be increased by adding up to four optional circuits, almost all of which are connected into the function and control section. Only the BCD outputs are taken from the analog-to-digital converter section. All of the optional circuits shown in the block diagram, see figure 3-1, and in the schematic diagrams in section V are described in this section. Optional circuits that are not applicable to a particular instrument should be disregarded.

3-4. FUNCTION AND CONTROL SECTION. The voltage under test is applied to the HI and LO input jacks. Front panel pushbutton switches operate the range control circuits which select the appropriate attenuator output for the desired range scale. The range control circuits consist of reed switches and steering diode networks which are especially adaptable for programmability. The

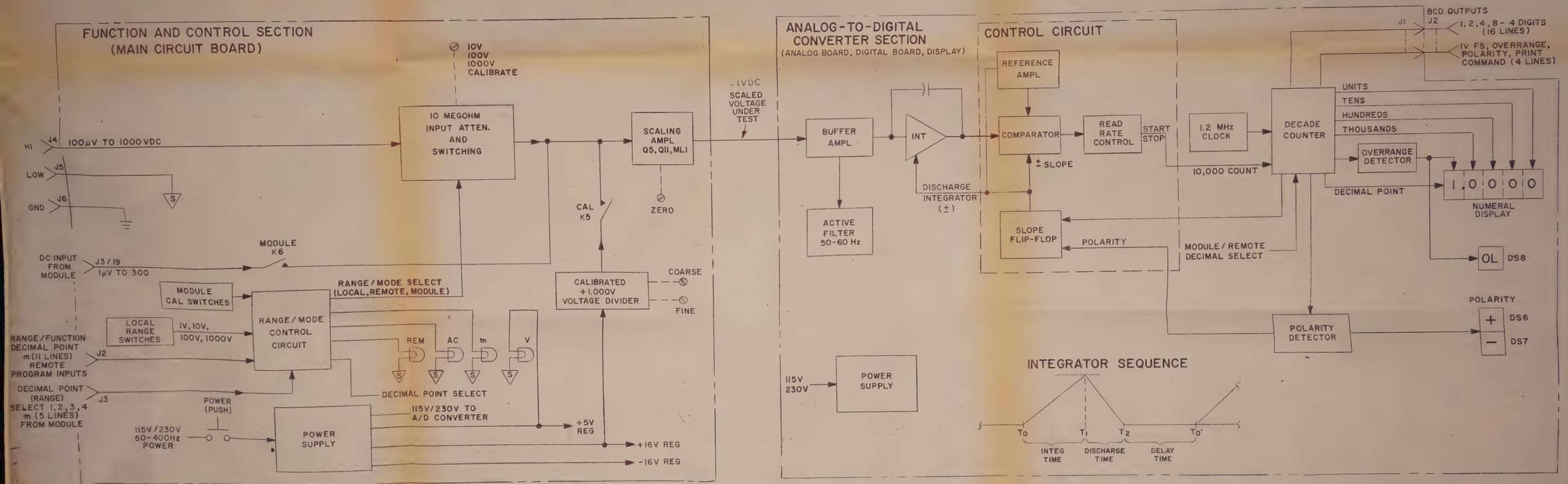


Figure 3-1. Model 3600 DC DVM
Functional Block Diagram

attenuator is a precision voltage divider with four outputs to cover the four DVM ranges. The 10V, 100V and 1,000V outputs are adjustable to permit calibration to the 1V range. Simultaneous with range selection, the range-control circuit positions the decimal point so that the display readout is compatible with the range and displayed with a minimum of ±0.01% accuracy. The attenuator output is scaled and applied to the analog-to-digital converter. The scaling amplifier is a unity gain amplifier which maintains the input voltage level to a high degree of accuracy while preventing interaction between the two sections of the DVM. The zero adjust potentiometer balances the amplifier with no input signal applied.

3-5. ANALOG-TO-DIGITAL CONVERTER SECTION. The input amplifier buffers the two sections of the DVM and provides negligible source loading and unity gain. Source loading is negligible due to the nulling of the input current with the current zero adjustment. The scaled output voltage is then processed by the integrator. The polarity of the voltage under test is sensed in this input amplifier and a signal generated which actuates polarity circuits for display. This function will be described later. The active filter attenuates ac that may be present on the voltage under test. Attenuation is approximately 40 dB at 50-60 Hz and is greater at higher frequencies.

3-6. The balance of the analog-to-digital converter section is essentially a voltage-to-time converter. A capacitor (integrator) is charged by a reference voltage for a known length of time, and then discharged to its original state by the input

voltage. Discharge time is proportional to the input voltage level. This period is accurately measured with a decade counter and displayed on a Nixie tube (numeral) readout. The analog-to-digital converter proportionally converts scaled input voltages from 0.0000 to 1.0000 volt into time intervals from 0 to 200 of the integration time. The sampling rate used is five per second. The conversion process is described in the following paragraphs and shown in the block diagram, figure 3-1.

3-7 Three time intervals are involved in each sampling. The first, integration time T_0-T_1, is a fixed interval defined by the time reference (clock) and the decade counter with a capacity of 10,000. The analog integrator is allowed to charge up to a voltage proportional to the reference voltage, starting at T_0 while the decade counter totals clock pulses. The slope flip-flop, triggered at T_0, ensures that the analog integrator and the decade counter both start at the same instant, from zero charge and zero count, respectively. Integration time ends at T_1 when the decade counter reaches a count of 10,000 pulses. At this instant, the integrator has a voltage at its output which is proportional to the reference voltage during the time interval T_0 - T_1.

3-8 The second time interval, T_1 - T_2 , commences when the decade counter reaches the 10,000 count. The input voltage is connected to the integrator; switching is accomplished by the slope flip-flop. At the same instant, the decade counter is automatically reset since it has reached a full count. The reference

[illegible] begins to discharge the integrator towards zero from its value at T_1 , and the counter counts up again. The end of the second time interval, T_2 is reached when the integrator is completely discharged to zero. Because the input voltage is used to discharge the integrator, the measured time interval $T_1 - T_2$ is proportional to the charge removed from the integrator. Since as much charge was removed from the integrator as was added during the charging interval, time interval $T_1 - T_2$ is also proportional to the input voltage. A 1 VDC average input to the integrator requires 10,000 clock pulses for discharge; a 0.5 VDC input requires 5,000 clock pulses for discharge. The reference voltage connected for charge of the integrator is both accurate and stable to maintain this relationship. Thus the count stored in the decade counter at instant T_2 represents the value of the input voltage.

3-9. The third time interval, $T_2 - T_o$, begins when the integrator is discharged to zero. The count stored in the decade counter at T_2 must be transferred to the display, and to the remote system if BCD outputs are used by the comparator and read rate control circuits. The comparator is essentially a voltage-to-time converter which monitors and compares the integrator voltage with the reference voltage and generates a pulse output that defines the time interval $T_o - T_2$. The trailing edge of this pulse occurs when the integrator voltage has been discharged to exactly zero, at T_2. The trailing edge synchronizes the action of the read rate control, which generates two control outputs. One output, a count inhibit pulse that disables the clock for 2 usec at T_2, keeps the decade

counter stable so that its count can be read out. The other output is a 2 usec read strobe that transfers the BCD count from the decade counter to the storage register. BCD data is converted to decimal form in the binary to decimal converter, which also drives the units, tens, hundreds, and thousands Nixie numeral display. T_2 transfer and display occur at the sampling rate, five per second.

3-10. The overrange numeral "1" indicator is illuminated when the decade counter goes overrange at T_2 (greater than 10,000 counts). The 10,000 count signal is applied through the overrange flip-flop and storage register to the indicator. The OL (overload indicator) is illuminated when capacity of the DVM system is overloaded (greater than 1.9999 volts) as indicated by 20,000 counts. The overrange and overload flip-flops control the illumination of the OL indicator.

3-11. The functions of the analog-to-digital converter adjustments are:

a. The current zero nulls the input circuit current so that no current is drawn from the source.

b. The Full Scale Calibrate control adjusts the reference voltage for a full scale reading of 1.0000 with a 1-volt input.

c. The potentiometer control R21, adjusts the integrator gain.

d. The Negative Polarity Gain control balances the integrator output for positive and negative signals.

e. The Zero Width control adjusts the comparator trigger level so that its pulse is triggered at 0.0000 volt.

3-12. Other functions of the analog-to-digital converter are as follows: The polarity oscillator and detector control the operation of the polarity indicators. The input voltage polarity is sensed by the input amplifier (paragraph 3-5), and the resultant output used to drive the polarity oscillator. A -3-volt signal is present for positive input voltages (1-volt full scale), and a +3-volt signal for negative input voltages. The oscillator is turned on for negative input voltage and its output detected to drive the negative (-) polarity indicator; otherwise, the positive (+) indicator is on. The location of the decimal point in the display is controlled directly by the range control circuit (paragraph 3-4). The minus ten digit gate causes the decade counter to subtract the first ten clock pulses in its count-up during each sampling period. This is done to compensate for settling time in the comparator which delays the instant at which T_2 occurs. Without compensation, a ten count error, approximately would result in the readout.

3-13. POWER SUPPLIES. Both the function and control, and analog-to-digital converter sections of the DVM have separate power supplies. The function and control section power supply develops ± 16 volts and +5 volts regulated outputs for its circuitry. The front panel V indicator is illuminated by the +5-volt supply. The analog-to-digital converter section develops ± 30-volt, ± 18-volt and +6.2-volt regulated outputs. The +6.2-volt output serves both as the regulation reference and as the critical reference amplifier input voltage.

3-14. MODULAR INTERFACE MODE. Operation of the MODULE pushbutton initiates the modular interface mode. Scaled input voltages are applied from the Model 3573M True RMS AC Module through interface [illegible] and through MODULE relay [illegible] to the input of the scaling [illegible]er. The analog-to-digital converter processes these voltages as described previously. Range control within the function and control section is not required since these are scaled as they enter the DVM. Decimal point positioning is required, however, to make the readout compatible with the input voltage. The decimal point select signals enter the function and control section through J3, and are applied to the range control circuit, where they actuate transistor switches, whose outputs control the decimal point function in the numeral display. Within the range control circuit, the decimal point select signal inhibits switching in the input attenuator, thus preventing interaction from the attenuator networks.

3-15. A fifth range-control line actuates the m (millivolt) indicator on the millivolt ranges. The AC indicator is illuminated and the polarity indicator inhibited in this mode by the action of the MODULE pushbutton switch. The characteristics of the modular interface signals are given in Section II.

3-16. CALIBRATION MODE. Operation of the CAL pushbutton initiates the calibration mode. A precision, stable, zener reference develops a calibrated test voltage at +1.0000 VDC. This is connected to the input of the scaling amplifier. The calibrated output is processed by the analog-to-digital converter to produce a +1.0000 readout. Coarse and fine adjustments enable precision setting of this voltage.

3-17. REMOTE PROGRAM MODE. All pushbuttons must be released for remote program operation. The REM indicator is illuminated with the pushbuttons released. Range and mode switching is controlled with 11 input lines entering the DVM through J4. DC input voltage for test is connected to the DVM at the HI and LO input jacks. The reed switches and steering diode networks respond to the program inputs to exercise the following DVM functions. The DVM operates in the same manner as in the local or modular interface mode.

a. 1V, 10V, 100V, and 1,000V ranges may be program selected (4 lines).

b. Decimal point position (1, 2, 3, 4) as appropriate with the selected range scale (4 lines).

c. Calibration mode of operation (1 line).

d. Modular interface mode of operation (1 line). In this case, DC voltage for test will be processed as described in paragraph 3-14. The AC indicator will also be illuminated.

e. The m (millivolt) indicator may be illuminated in conjunction with modular interface (1 line).

3-18. BCD OUTPUTS. BCD outputs are available for use in remote system evaluation or printout systems. All BCD outputs are taken from a storage register in the analog-to-digital converter section and supplied to the remote system through J4. The following outputs are available. All are DTL and TTL compatible. Refer to section II for their characteristics.

a. 4-wire binary code (1, 2, 4, 8) of each display numeral (16 lines).

b. 1V full scale bit (10,000 count), overrange bit (20,000 count), polarity bit (3 lines).

c. A print command pulse (2 usec read strobe pulse).

3-19. THEORY OF OPERATION, FUNCTION AND CONTROL SECTION.

3-20. RANGE/MODE CONTROL. The range and mode control circuits consist essentially of the K1 through K6 reed relays, and diode gate networks (see figure 5-1). Coil elements of the reed relays may be energized locally by depressing the desired front panel range or mode pushbutton, or from remote program inputs at connector J4. In local operation, a selected pushbutton of switch assembly S2 places ground on an associated relay which is energized by the +5-volt supply. Contacts of the relay select the appropriate attenuator output for the range scale. The 10V, 100V, and 1,000V attenuator sections are individually adjustable to permit their calibration against the 1V range.

3-21. The relay ground by means of R2, R4 and R6 respectively, is also applied through a diode CR20 through CR23 or CR14, to decimal point line (DP 1, 2, 3, or 4). The ground on the decimal point line turns on the decimal point indicator in the display.

3-22. Relays K5 and K4 connect either the calibrated +1.0000-volt test voltage or the input voltage from J3-12 to the scaling amplifier input. In the MODULE mode, AC indicator DS1 is illuminated by the +5-volt supply and the ground connection. Also, the normally-closed ground of MODULE pushbutton S2F is opened. This disconnects REM indicator DS3.

3-23. The same range and mode functions may be selected in the remote mode by application of a ground to the desired function,

tacts 36 through 41 of S4. Diodes CR9 through CR13 is [illegible] remote program input lines from switch assembly S2 and the decimal point select circuit. The decimal point indicator is illuminated by a ground applied directly to the numeral display decimal point lines in the digital section. With all local pushbuttons released, REM indicator DS3 is illuminated by a ground through normally-closed contacts of S2A through S2F.

[illegible]. In the MODULE mode, range selection is accomplished within the converter module. Decimal point position is selected with a +2-volt level (TTL high) applied to J3-15, 14, 4, and 3 which turns on respectively, transistor switch Q6 through Q9, pulling the associated decimal point line to ground and illuminating the decimal point indicator in the display. Switch Q10 turns on m (millivolt) indicator DS2 in a similar manner.

[illegible]. SCALING AMPLIFIER. The scaling amplifier is a high-gain, high-feedback-type operational amplifier utilizing dual FET Q5 as the input and feedback amplifier and micrologic amplifier module IC1 to provide the high gain required in the loop. The open loop gain of IC1 is approximately 100,000. The input voltage is applied to the signal gate of FET Q5. Transistor Q11 provides a stable constant current source for the FET. Inverse feedback from IC1 is applied to the other gate of Q5. The high gain and high feedback results in a very stable unity-gain amplifier which accurately follows the input voltage. Zero-adjust potentiometer R23 allows the amplifier to be balanced with no input voltage. Diodes CR1 and CR2 protect the signal gate from overload and possible damage.

[illegible] +1.000V CALIBRATOR. The calibrator circuit consists of a precision voltage divider and regulator connected across the regulated +16-volt supply (see figure 5-2). The precision voltage divider is connected across zener regulator CR16, which has a breakdown of 9.1 volts. Coarse (1V COARSE ADJ) and fine (1V FINE ADJ) adjustment potentiometers R42 and R41 permit precise set[illegible] calibrated voltage.

3-27. POWER SUPPLIES. Three rectifier power supplies provide the power required by the function and control section of the DVM [illegible]. The three power supplies are full-wave, [illegible] rectifier circuits which draw power from separate secondary windings of power transformer T1. The primary windings may be energized by 115V or 230V. Line voltage switch S4 connects the [illegible] mary windings for operation with the line voltage available. [illegible] is drawn from the same input for operation of the analog-to-digital converter section which contains its own power supplies.

3-28. Each rectifier circuit operates into a capacitive filter and is series regulated. The positive and negative 15-volt supplies are identical except for the ground connections. The series pass regulator element is controlled by a micrologic amplifier module (IC2 and IC3). The output voltage is adjusted by potentiometers R33 and R36. The +5-volt regulator is similar except that the output is fixed by zener regulator CR15. Also, series pass transistor Q3 is controlled by Q4. Power indicator DS5 is connected across the unregulated +5-volt output. Voltage indicator DS4 is connected across the regulated +5-volt output. Both are illuminated when power is applied to the DVM.

3-29. THEORY OF OPERATION, ANALOG-TO-DIGITAL CONVERTER SECTION.

3-30. ACTIVE FILTER CIRCUIT. The active filter is a low impedance nulling device which effectively filters out any AC components that may be superimposed on the input voltage (see figure 5-3). The AC components are coupled through C39 to the input of Darlington-connected amplifier Q47 - Q48. The collector signal, which is inverted, drives emitter follower Q49, whose output voltage, developed across emitter resistor R72 is equal to and opposite the AC component. This inverted signal is fed back to the input line through C40. The effect is to null out the AC component so that only a pure DC signal remains at the base of Q6. Zener regulator CR15 stabilizes the emitter supply of Q49 and the base supply of Q47.

3-31. INPUT AMPLIFIER CIRCUIT. The input amplifier is a unity gain, high-feedback-type amplifier utilizing cascade differential amplifiers to attain the high open loop gain and complementary output pairs in the feedback loop. The open loop gain is approximately 25K. The input differential amplifier consists of Q6 and Q7, with Q8 serving as the constant current source (see figure 5-3). The input voltage to be measured is coupled to the base of Q6; the input to the Q7 base is the feedback signal, from the Q16 and Q17 emitters. Input circuit loading is virtually eliminated due to the high input impedance offered by the R9, R10, Q2 and Q3 network and the current supplied by Q1. Input Current zero potentiometer R3 adjusts the current to null out any current taken from the source.

3-32. The differential outputs from Q6 and Q7 drive the second differential consisting of Q9 through Q12. The collectors of Q10 and Q11 drive the base and collector of Q13, which form a single-ended composite output from the differential. The output voltage present at the collector of Q13 is -3 volts for a +1-volt full scale input signal and +3 volts for a -1-volt full scale input signal. The composite output drives complementary emitter follower output pairs Q14 through Q17, which provide the integrator drive and the feedback signal to close the loop. The emitter followers are pulsed on and off at T_0 and T_1 by switches in the reference amplifier. When on, the emitter followers drive the integrator.

3-33. INTEGRATOR CIRCUIT. IC1, Q18, and Q19 make up the integrator (see figure 5-3). C3 is the integrating capacitor. This circuit is conventional except that is is charged to the input level through emitter followers Q15 and Q17 and discharged to the level of the highly accurate reference voltage. The output voltage present at the collectors of Q18 and Q19 consists of a negative slope discharge waveform whose steepness (time to full discharge) is proportional to the input voltage. This waveform is applied to the comparator for detection of the precise instant zero crossover is reached. Integrator IC1 feedback is taken from the emitter of Q19. Potentiometer R21 adjusts the gain of the integrator; full scale calibrate control R20 adjusts the integrator for balanced output with positive and negative input voltages.

3-34. REFERENCE AMPLIFIER CIRCUIT. The reference amplifier requires a very accurate and stable reference input voltage to

maintain the accuracy of the system. Reference zener diode CR11 provides this +6.2V voltage, which is applied to the base of Q20. Q20 supplies drive current for the emitter of Q21, which develops the drive voltage for Darlington-connected amplifier Q22-Q23. The reference voltage is approximately +12 volts DC and is present at the collector of Q23. Full Scale Calibrate potentiometer R26 permits small adjustment of the reference voltage to obtain a full scale reading of exactly 1.0000 volt.

3-35. COMPARATOR AND CONTROL CIRCUITS. The comparator is a pulse generator consisting of transistors Q27 through Q33 (see figure 5-3). Q27 and Q29 are FET which switch the pulse on and off. The pulse is initiated by application of the reference voltage at the gate of Q27 (paragraph 3-36) and terminated when this voltage drops below a prefixed level. Q29 is switched on by the source voltage from Q27 when it is turned on. Q28, which provides bias current for the gate of Q29 has its current adjusted by zero width control R32 which balances the FET currents and sets the trigger level for 0.0000-volt input. Transistor Q30 serves as the source follower load for Q29. Q33 is turned on when Q29 is on, and Q31 and Q32 are both off, thus enabling a high level pulse at the collector of Q32. The pulse is terminated by the slope flip-flop Q45, Q46. The comparator pulse is applied through transformer T_3 to the read rate control.

3-36. The slope flip-flop controls the application of the reference voltage to the comparator, integrator, and input amplifier. This flip-flop is a bistable multivibrator consisting of Q45 and Q46 (see figure 5-3). Q45 is turned off at T_0 and the flip-flop toggled at T_1 (count of 10,000 clock pulses). With Q45 off, its collector voltage goes high, back biasing CR5 and permitting the reference voltage to be applied through Q26, a diode-connected transistor, to the gate of FET Q27, thus initiating the comparator pulse. Capacitor C5 in the comparator charges to the reference voltage level at the same time. The low level from the Q46 side of the flip-flop turns on Q24, connecting the +18-volt supply to the integrator, and input amplifier for the charge function. The integrator charges towards input voltage level until T_1 , when a count of 10,000 is reached.

3-37. At T_1 the flip-flop is toggled to the opposite state, Q45 is turned on and Q46 off. With Q45 on, its collector is low, placing a ground on the anode of CR5 and clamping the reference voltage to ground. Also, the high level at the collector of Q46 turns off Q24. At this time, the Q25 base is biased by the reference level stored on C5 and the collector sees the integrator output. The result is that Q25 is forward biased, permitting the integrator to discharge to the reference on C5. Q24 becomes back biased at the instant the integrator is fully discharged (zero crossover). Note that discharge current from C5 maintains FET Q27 on. At zero crossover, discharge current stops, turning off Q27 and terminating the comparator pulse. The switching characteristics of slope flip-flop Q45-Q46 and of switch Q24 result in a 12 usec interval

approximately at T_1 during which the clock continues to run but the integrator cannot discharge. Without compensation for this settling time, a readout error would result. To compensate, ten clock pulses, equal to the settling time, at T_1 of each sampling period are not counted. Thus, the integrator discharge and the count-up begin at precisely the same instant.

3-38. The slope flip-flop is triggered when the decade counter reaches 10,000. The output of thousands decade IC12 (figure 5-4) goes high and turns on Q12, setting IC14A. IC14A is triggered by a negative transition. Its Q output is differentiated and applied through Q10, T2, Q44 and CR12 to trigger on Q45. The flip-flop is reset at T_2 by a negative-going pulse from the read rate control.

3-39. READ RATE CONTROL CIRCUIT. Transistors Q13, Q14, Q17, and Q18 comprise a free-running multivibrator that sets the sampling rate of the analog-to-digital converter (see figure 5-4). The multivibrator rate is five per second and is set by the time constant of C15, C16, and R50. Switching is synchronized by the negative-going trigger pulse derived from the trailing edge of the comparator pulse at T_2. Before triggering, Q13, is held on (its base is tied to a positive voltage) and Q18 is off. Q16 is also held off by the positive voltage at its base. The comparator pulse is differentiated by C20. The leading edge has no effect on Q16. The trailing edge produces a negative-going pulse which turns Q16 on and Q13 off, changing the state of the multivibrator. The multivibrator remains in this state until the time constant allows Q14 to go off again. Positive-going output pulses, 2 usec in duration,

are taken from the collector of Q13 and the emitter of Q18. The emitter pulse is the read strobe. This pulse strobes the storage register for storage of the decade counter data at T_2. The read strobe is also applied to inverter Q9 which furnishes a print command (negative 2 usec pulse) for use with external equipment. The Q13 collector pulse is applied to the count-inhibit gate to inhibit clock operation during this interval. The collector pulse is also applied to differentiator C21-R48. The trailing edge of the pulse resets IC14B if it was set.

3-40. CLOCK AND COUNT INHIBIT GATE. The clock provides a continuous train of pulses occurring at a rate of 1.2 MHz. The clock consists of a conventional oscillator, Q4, and pulse-shaper Q5 (see figure 5-4.) Components L1, C3, C5, and C6 determine the resonant frequency of the oscillator. C6 adjusts the frequency. Diode CR1 and C1 and C2 filter oscillator input power for frequency stabilization. Diodes CR2 and CR3 are also utilized for frequency stabilization by fixing the base bias. Oscillations are coupled through C7 to the pulse shaper. Q5 inverts and squares the oscillator waveform to provide a 5-volt pulse with a fast clean negative transition which clocks the units decade counter at IC9, pin 9. Clock output pulses are inhibited during the read strobe interval by NAND gate IC51 B and Q6. One input to IC15B is the read strobe pulse, which is low during the count interval. The other input is from the clock through Q6. As long as the strobe input is low, the output of IC15B follows the clock pulse. When the read strobe goes high the output of IC15B is clamped to a low level, disabling the clock and inhibiting the count. Q6 responds to the negative pulse to speed the transition.

3-41. DECADE COUNTER. (See figure 5-4). The decade counter consists of IC9 through IC12 connected in a ripple-counter configuration that is modified to omit the first ten clock pulses in the count-up. Gates IC15A, C, and D and Q7 control the minus ten function. In a straight ripple counter, the carry outputs are connected from decade to decade. In this configuration, the 1's carry drives Q7, and the carry input to the tens decade IC10 comes from IC15A. Also a negative transition is required to clock IC10. IC15C and IC15D make up a latch flip-flop which provides an enable input to IC15A. The latch flip-flop is triggered by a negative-going pulse at T_1 from IC14B, pin 9 which occurs at the start of the count-up. The output of IC15C goes low, disabling IC15A. The carry output from IC9 is only during the tenth clock pulse and then goes high again as the count continues. Q7 inverts this carry pulse placing a high level at the count line, pin 1 of IC15A. The tenth clock pulse is not "carried" to IC10/, however, because IC15A is disabled. The trailing edge of this tenth pulse produces a negative-going pulse which triggers IC15C, latching the flip-flop with a high level at the enable line of IC15A. Thereafter, the carry pulse is coupled through IC15A to the tens decade (a negative transition occurs). Counting continues until IC15D is reset again for a new sampling.

3-42. STORAGE REGISTER AND DISPLAY. The storage register consists of integrated circuits IC5 through IC8 (see figure 5-4). The register accepts the BCD bit data present in the decade counter when strobed. Data stored in the register is coupled to binary-to-decimal converter circuits IC1 through IC4, in which binary

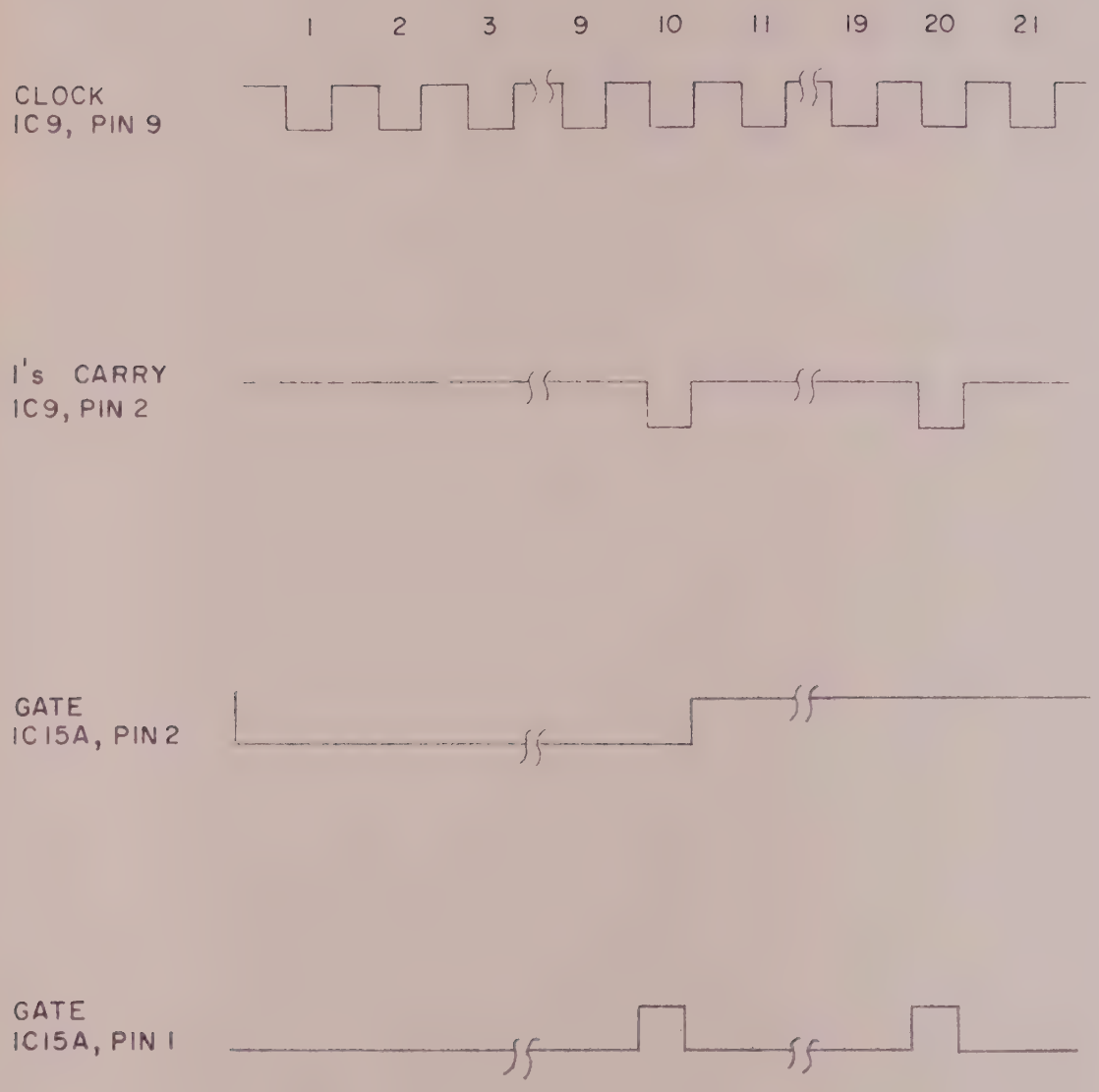


Figure 3-2. Minus Ten Digit Gate Waveforms

conversion to decimal is made. The numeral display is a conventional Nixie readout operated from IC1 through IC4. Decimal point positioning in the Nixie display is controlled from the function and control section of the DVM. Storage register IC5 through IC8 also supplies BCD outputs 1-2-4-8 for use by external equipment. Logic levels used in these integrated circuits are a high level (+4 volts) or ground.

3-43. POLARITY DETECTOR CIRCUIT. (See figure 5-4). The polarity control circuit consists of polarity oscillator Q41 through Q43, transformer T1 (figure 5-3) polarity detector Q11, part of storage register IC13, and the indicators and their drivers (figure 5-4). Input voltage polarity is sensed in the input amplifier (figure 5-3); the collector of Q13 goes positive for a negative input voltage. Q41 is a switch which turns Q42 on or off; Q42 is off with a positive output from Q13 (negative input voltage). With Q42 off, Q43 is permitted to oscillate. Otherwise, the supply of Q43 is clamped to ground. Oscillator power is coupled through transformer T1 to the base of polarity detector Q11 (figure 5-4), turning it on, and furnishing a low level at pin 11 of IC13. Pin 10 of IC13 also goes low turning off driver Q2. Negative (-) polarity indicator DS7 lights with Q2 turned off. With a positive input voltage, the polarity oscillator (figure 5-3) is disabled. Q11 (figure 5-4) is off, and a high level at pin 10 of IC13 turns driver Q2 on. This sequence connects a ground path to positive (+) polarity indicator DS6 and lighting it. The polarity indicator circuit is modified for use with the [illegible] option. (See option #3 on figure 5-4.)

In this option, section F of MODULE pushbutton of switch S2 is connected so that when it is depressed, the ground-return line from DS7 and Q12 is opened, disabling both polarity indicators.

3-44. POWER SUPPLIES. (See figure 5-4). Three power supplies provide the power required by the analog-to-digital converter. Two are full-wave diode rectifier circuits and the third is a half-wave rectifier. All three draw power from separate windings of transformer T1 located on the digital circuit board (A3) of the converter section (see figure 5-4.) Primary power is taken from the transformer T1 in the function and control section (see figure -1).

3-45. The +5-volt supply, on A3 is developed from bridge rectifier CR9 through CR12, is unregulated and supplies +5-and +4-volt power for all the digital components. The -250-volt output from half-wave rectifier CR8 supplies power for the Nixie display tubes. Power for operation of the analog circuits is developed on the analog board, A2 (figure 5-3) with bridge rectifier CR7 through CR10 and separate positive and negative regulators. Both outputs are referenced to ground. The positive regulator utilizes Q35 and Q36 in a conventional differential amplifier configuration feeding series pass transistor Q34. CR11 provides a fixed 6.2-volt reference for regulation. The regulator supplies +30-volt and +18-volt outputs. Transistor Q39 is diode-connected and operates in the zener region to provide the +18-volt output. The negative regulator is similar except that Q37 serves as the control for series pass transistor Q38. The base of Q37 is clamped to a fixed level from the regulated +30-volt output.

SECTION IV

MAINTENANCE

4-1. GENERAL.

4-2. This section contains preventive and connective maintenance and calibration instructions for the DVM. A list of test equipment required for maintenance of the unit, minimum performance standard checks, troubleshooting data and calibration procedures are included. No attempt should be made to repair the instrument until one is thoroughly familiar with the information presented in this section.

4-3. TEST EQUIPMENT REQUIRED.

4-4. The test equipment required for maintenance and calibration of the DVM is listed in table 4-1. Equipment having similar characteristics may be substituted for those listed in the table.

Table 4-1. Test Equipment Required

EQUIPMENT	MANUFACTURER AND MODEL
Voltage Standard	John Fluke, Model 332B
Wide Range Oscillator	Hewlett-Packard, Model 200CD
Metered Variac	Superior No. VS116B
Voltmeter	Singer 3600 or equivalent
Oscilloscope	Tektronix, Model 454

4-5. PERFORMANCE STANDARDS.

4-6. Performance standards checks are a complete test of the DVM to detect degradation of performance and to serve as a confidence check for verifying compliance with published specifications listed in section I. The DVM should be checked for performance after every major repair and at scheduled recalibration and certification periods. Scheduled performance checks are recommended after 90 days of operation. Performance standards checks for the DVM are given in table 4-2. The instrument should be energized and permitted to stabilize for 30 minutes prior to the checks.

Table [illegible]. Performance Standards Check

[illegible]	PURPOSE	PROCEDURE	ACCEPTABLE INDICATION
1	To check accuracy.	a. Switch to the 1V range. Short out the HI and LO input jacks and adjust the ZERO potentiometer (front panel) for a readout of 0.0000 ±3 digits.	
		[illegible]. Connect the voltage standard to the DVM input jacks. Apply the following voltages and observe the readout for accuracy:	b. The readouts should be within the following tolerances:

Input Voltage	Tolerance
+2.0000	+[illegible] digits
+1.9000	+[illegible] digits
+1.8000	+[illegible] digits
+1.7000	+[illegible] digits
+1.6000	+[illegible] digits
+1.5000	+[illegible] digits
+1.4000	+[illegible] digits
+1.3000	+[illegible] digits
+1.2000	+[illegible] digits
+1.1000	+[illegible] digits
+1.0000	+[illegible] digits
+0.9000	+[illegible] digits
+0.8000	+[illegible] digits
+0.7000	+[illegible] digits
+0.6000	+[illegible] digits
+0.5000	+[illegible] digits
+0.4000	+[illegible] digits
+0.3000	+[illegible] digits
+0.2000	+[illegible] digits
+0.1000	+[illegible] digits
0.0000	+[illegible] digits

[illegible]	[illegible]	PROCEDURE	ACCEPTABLE INDICATION
		. Repeat step b for negative polarity input voltages	
		[illegible]. Switch to the 10V range. Set the voltage standard to +15.000 volts. Repeat for negative polarity input.	[illegible]. The readout should be 15.000 ±4 digits and of proper polarity.
		[illegible]. Switch to the 100V range. Set the voltage standard to +150.00 volts. Repeat for negative polarity input.	[illegible]. The readout should be 150.00 ±4 digits and of proper polarity.
		[illegible]. Switch to the 1,000V range. Set the voltage standard to 1000.0 volts. Repeat for negative polarity input.	[illegible]. The readout should be 1000.0 ±3 digits and of proper polarity.
[illegible]	To check the normal mode rejection ratio (NMRR).	[illegible]. Switch to the 1V range. Set the voltage standard to 1.000 volt and connect through a 1K ohm resistor. Connect a H-P 200 CD oscillator to the DVM HI input jack through a 1 ufd capacitor. Ground straps should be connected between the LO and ground jacks of the oscillator and standard.	[illegible]. The readout should be 1.0000 ±3 digits and of proper polarity.
		b. Set the oscillator for a 1-volt peak-to-peak sine wave at 50 Hz.	[illegible]. The readout should not vary more than ±10 digits.

[illegible]	PURPOSE	PROCEDURE	ACCEPTANCE INDICATION
[illegible]	To check the common mode rejection ratio (CMRR).	a. Disconnect the ground shorting strap from the LO jack and short the HI and LO jacks together.	
		[illegible]. Connect the voltage standard between the HI input jack and the ground jack. Set for an output of 100 volts.	b. The readout should be 0.0000 ±1 digit maximum.
[illegible]	To check power consumption and regulation.	a. Connect the DVM to the metered variac. Slowly increase the line voltage to 120 VAC. Observe power consumption.	a. Power should not exceed 10 watts.
		b. Connect the voltmeter to monitor the +16-volt regulated output at +16 TP. Vary the line voltage from 108 to 132 volts. Monitor the -16-volt output at -16 TP and repeat the high/low line voltage variation.	b. The 16 volt outputs should not vary more than ±25 mV.
		[illegible]. Monitor the +5-volt regulated output at +5 TP. Vary the line voltage as in step b.	[illegible]. The +5 volt output should not vary more than ±0.6 volt.
		d. Repeat the accuracy test (step 1) at +1.000-volt input. Vary the line voltage as in step b.	d. The readout should remain within +1.0000 ±2 digits.

PURPOSE	PROCEDURE	[illegible]
To check the internal calibration voltage.	Switch to the calibration mode and observe the readout.	The readout should be +1.00, ±3 digits.
To check modular interface.	a. Switch to the module mode.	
	b. Connect a source of +2 volts to pins 15,14,4,3 on connector J3. Observe the decimal point location for each action.	b. The decimal point should be located as follows: DP Location xxx.x xx.xx x.xxx .xxxx
	c. Connect the +2-volt source to pin 16 on J3.	c. The m (millivolt) indicator should illuminate.
To check remote programming.	Command Remote from the Front Panel	
	a. Ground Pin 36 Programming Conn., J4	a. The DVM should be [illegible] range.
	b. Ground Pin 37 Programming Conn., J4	b. The DVM should be [illegible] range.
	c. Ground Pin 38 Programming Conn., J4	c. The DVM should be [illegible] range.
	d. Ground Pin 39 Programming Conn., J4	d. The DVM should be [illegible] range.

[illegible]	[illegible]	[illegible]	[illegible]
	To check remote [illegible] (Cont)	[illegible]. Ground Pin 40 Programming Conn., J4	e. The DVM should be in [illegible] range.
		[illegible]. Ground Pin 41 Programming Conn., J2	f. The DVM should be in [illegible] Module mode.
		[illegible]. [illegible] Conn., J4	[illegible]. [illegible]
		h. Ground Pin 27 Programming Conn., J4	h. DP 3 should come [illegible]
		i. Ground Pin 28 Programming Conn., J4	i. DP 2 should come [illegible]
		j. Ground Pin 29 Programming Conn., J4	j. DP 1 should come [illegible]
	To check the BCD outputs.	a. Connect the BCD output connector, J4, to a 5-line or more printer capable of accepting 1-2-4-8 positive true logic (TTL/DTL compatible) such as the Monsanto 510A or similar devices.	
		b. Apply voltages to the input connectors of the DVM from +0.1111 to +1.9999 volts on the 1-volt range with the voltage source. Printout should be identical to the readout.	

4-8. TROUBLE LOCALIZATION.

4-9. Malfunctions of the DVM are generally localized from the nature of the trouble symptom or from the performance verification test that failed. Further localization can frequently be accomplished by operating the pushbuttons and noting the response. Signal tracing and/or signal substitution can also be employed effectively. The calibration test voltage, for example, exercises the scaling amplifier and the analog-to-digital converter. Also, the scaling amplifier output may be replaced by an external, calibrated voltage applied directly to the analog-to-digital converter. A thorough understanding of the operation of the DVM is essential in any approach.

4-9. As a first step in troubleshooting, check the power supply voltages and adjust if necessary. Then, localize the trouble to a functional section of the DVM as described above. If the analog-to-digital converter is suspect, it should be checked using the signal substitution method of the converter test of paragraph 4-14 before proceeding. Table 4-3 provides procedures for localizing malfunctions to a section, circuit board, and most often to a circuit level. Remove the top cover of the DVM for access to the A1 components. The analog-to-digital converter (A2 and A3) must be removed from its mounting and the two circuit boards separated to gain access to each. The interconnecting cable between the boards must remain connected for checkout and testing.

4-[illegible]. Resistance and/or voltage measurements are used to isolate troubles to a circuit level (and to defective components). For analog-to-digital converter troubles, waveform analysis may be more helpful. Voltage data for the function and control section is given in table 4-4. Resistance and continuity information can easily be derived from the schematic diagram, figure 5-1. Voltage data for the analog-to-digital converter is given in table 4-5; figures 3-2 and 3-3 provide normal timing waveforms. Resistance and continuity information is contained in schematic diagrams, figures 5-3 and 5-4. Calibration and performance should be checked following the repair.

STEP	INSTRUCTIONS	NORMAL INDICATION	IF INDICATION IS NORMAL	IF INDICATION IS ABNORMAL
1	Connect power and energize DVM. Measure power supply voltages as directed in steps a,b,c, and e, paragraph 4-17.	a. +16V b. -16V c. +5 ±0.5V e. (A2) +18 ±3.0V +30 ±5.0V -18 ±[illegible]V [illegible] ±[illegible]V (A3) +5 ±[illegible]V +4 ±[illegible]V	Proceed to step 2.	Check defective power supply and adjust. Refer to tables 4-4 and 4-5 for voltage data.
2	Connect voltage standard to input jacks and set for 1.0000 volt. Depress 1V pushbutton. Connect external DVM to J2-12 to monitor scaling amplifier output.	+1.0000V	Proceed to step 4.	Proceed to step 3.
3	Connect external DVM to gate (pin 3) of FET Q5.	+1.0000V	Check scaling amplifier circuit (Q5,Q11,IC1)	Check 1V range switch S2A and reed relay.
4	Set voltage standard to 10.000V and depress 10V pushbutton. Monitor voltage at J2-12.	+10.000V	Proceed to step 5.	Check 10V range switch S2B and reed relay K1.
5	Set voltage standard to 100.00V and depress 100V pushbutton. Monitor voltage at J2-12.	+100.00V	Proceed to step 6.	Check 100V range switch S2C and reed relay K2.

[illegible]	[illegible]	NORMAL INDICATION	IF INDICATION IS NORMAL	IF INDICATION IS ABNORMAL
[illegible]	Set voltage standard to 1000.0V and depress 1000V pushbuttons. Monitor voltage at J2-12.	+1000.0V	If calibration option, proceed to step 7, otherwise proceed to step 8.	Check 1000V range switch S2D and reed relay K3.
[illegible]	Depress CAL pushbutton. Monitor voltage at J2-12.	+1.0000V	Proceed to step 8 with module option; otherwise proceed to step 9.	Check CAL switch S2E and reed relay K5.
[illegible]	Connect voltage standard to J3-12 and ground and set for 1.0000V. Depress MODULE pushbutton. Monitor voltage at J2-12.	+1.0000V	Proceed to step 9.	Check module switch S2F and reed relay K4.
[illegible]	Depress the 1V, 10V, 100V and 1000V pushbuttons and observe the decimal point positioning.	x.xxxx xx.xxx xxx.xx xxxx.x	Function and control section normal. Proceed to step 10.	Check diodes CR14, and CR20 through CR23.
[illegible]	Depress 1V pushbutton and set voltage standard to +2.0000V.	OL indicator lights.	Proceed to step 11.	Check analog-to-digital converter section, step

Table 4-[illegible]. [illegible]

STEP	[illegible]	NORMAL INDICATION	IF INDICATION IS [illegible]	IF INDICATION IS [illegible]
[illegible]	Apply +1.000V and then -1.0000V with voltage standard.	Appropriate polarity indicator lights.	Proceed to step 12 for checkout of analog-to-digital converter.	Check analog-to-digital converter section, step [illegible]
[illegible]	Disconnect DC input line to analog-to-digital converter at J1-12. Connect a voltage standard to J1-12. Set to +1.0000V. Monitor voltage at J1-10 with external DVM.	+1.0000V	Proceed to step 13.	Check active filter and input amplifier circuits. Refer to table 4-5 for voltage data.
[illegible]	Check integrator waveform at collector of Q19.	See figure 3-2 for waveform.	Proceed to step 21.	If levels are wrong check voltage reference or integrator. If incorrect waveform check switches. If no waveform proceed to step 14.
[illegible]	Check for slope flip-flop trigger at A3Q10 collector.	See figure 3-2 for waveform	Proceed to step 15.	Proceed to step 16,
[illegible]	Check for trigger at collector of A2Q44.	Same as step 14.	Check slope flip-flop. Refer to table 4-5 for voltage data.	Check T2, Q44.

[illegible]	NORMAL INDICATION	IF INDICATION IS NORMAL	IF INDICATION IS ABNORMAL
Check Clock output waveform at IC9, pin 9.	0.8 usec pulse.	Proceed to step 17.	Check clock circuit.
Check tens decade input waveform at IC10, pin 9.	8 usec pulses.	[illegible] 18.	Check count inhibit gate circuit units decade IC9.
Check hundreds decade input at IC11, pin 9.	80 usec pulses.	Proceed to step 19.	Check tens decade IC10.
Check thousands decade input waveform at IC12, pin 9.	800 usec pulses.	Proceed to step 20.	Check hundreds decade IC11.
Check thousands decade carry at IC12, pin 2.	8 msec pulses.	Check Q12 and [illegible].	Check thousands decade IC12.
Check comparator waveform at A2 Q32 collector. Check with 0.0000V input and 1.0000V input.	[illegible] figure 3-2 [illegible] waveform.	Proceed to step 17	Check comparator circuit.
Check read rate control trigger at A3 Q16 base.	[illegible] figure 3-2 [illegible] waveform.	Proceed to step 18.	Check T3.
Check read rate control outputs at Q13 collector and Q18 emitter.	[illegible] figure 3-2 [illegible] waveform.	Proceed to step [illegible].	Check read rate control circuit. Refer to table 4- for voltage data.

4-11. ADJUSTMENTS AND TEST POINTS.

4-11. The location of adjustment potentiometers and their functions are illustrated in figure 4-[illegible] of the main chassis and main circuit board. Significant test points are also called out.

4-12. ANALOG-TO-DIGITAL CONVERTER TEST.

4-12. This procedure may be followed during trouble isolation when the converter section is suspect, or as a confidence check. The procedures could be performed with the converter section connected in the DVM. AC power is derived from the power transformer on the main circuit board. However, the DC input line at J2-12 (figure 5-3) should be disconnected to isolate the function and control section (scaling amplifier) from the converter section. Remove the top and bottom covers of the DVM for access.

a. Connect DVM to the metered variac.

b. Slowly increase the line voltage to 115 VAC. Check that the proper consumption does not exceed 8.0 watts.

NOTE

Allow 15 minutes warm-up time before making any further checks.

c. Short pins 8 and 12 on J2 together. Check that the readout is 0.0000 ±1 digit.

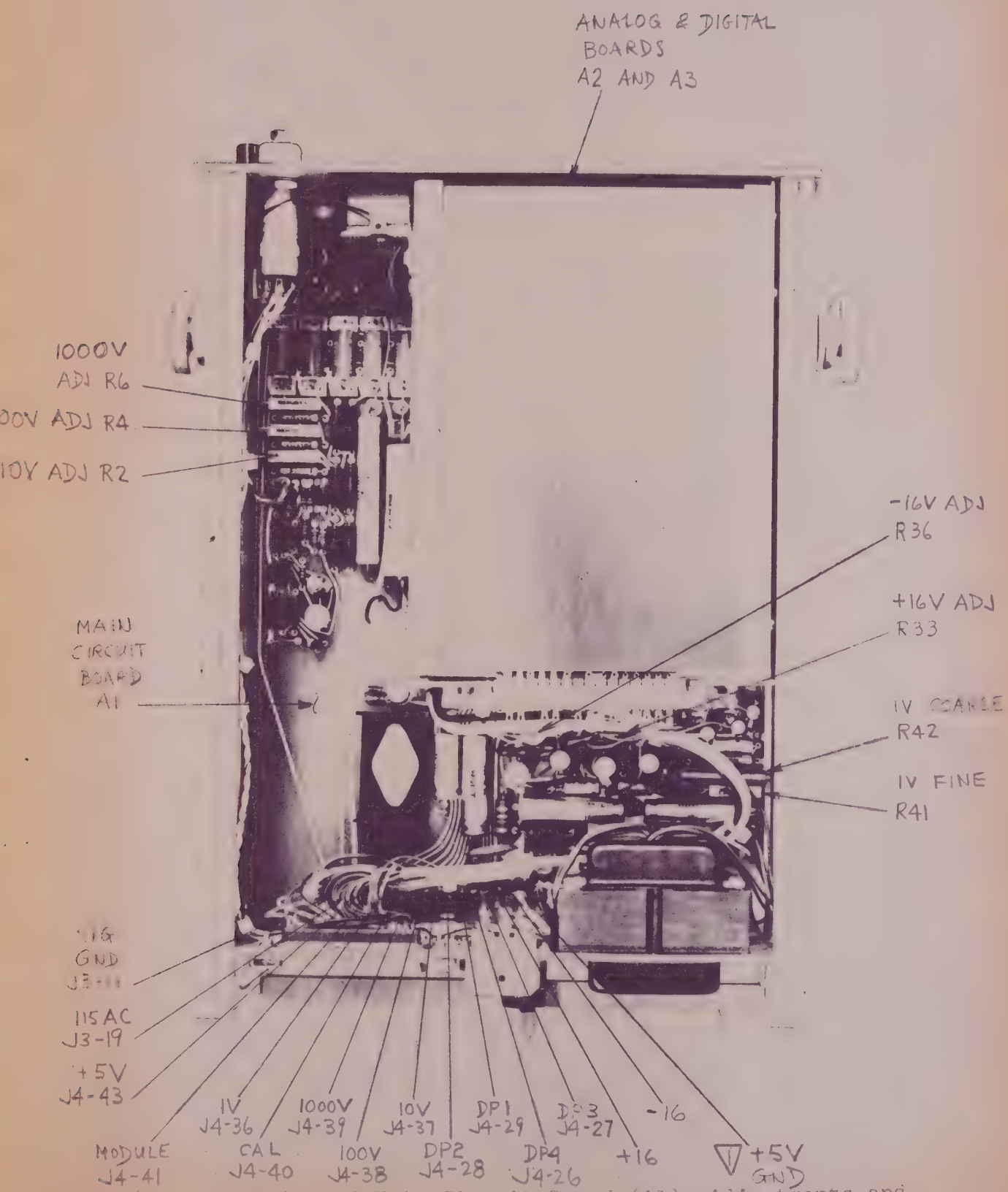


Figure 4-1. Chassis and Main Circuit Board (A1), Adjustments and Test Points

d. Connect a voltage standard between J2-12 (High) and J2-8. Apply +1.0000 volts to the converter. The readout should be +1.0000 ±2 digits.

e. Apply -1.0000 volts to the converter. The readout should [illegible] ± digits.

f. Apply the following voltages. The readout should be within tolerance indicated.

Input Voltage	Tolerance
+1.9999V	±4 digits
+1.8888V	±4 digits
+1.7777V	±4 digits
+1.6666V	±4 digits
+1.5555V	±3 digits
+1.4444V	±3 digits
+1.3333V	±3 digits
+1.2222V	±3 digits
+1.1111V	±2 digits
+1.0000V	±2 digits
+0.8888V	±2 digits
+0.7777V	±2 digits
+0.6666V	±2 digits
+0.5555V	±2 digits
+0.4444V	±1 digit
+0.3333V	±1 digit
+0.2222V	±1 digit
+0.1111V	±1 digit
+0.0000V	±1 digit

g. Repeat step f using negative polarity input voltages.

Note

Observe the Nixie numerals for partial numbers and for proper operation at the same time.

h. Apply +1.0000 volt to the converter. Vary the line voltage from 105 to 132 volts with the Variac. The readout should not change more than 2 digits.

4-15. CALIBRATION.

4-16. BASIC DVM. Calibration of the DVM is required following repairs, and at the following calibration intervals:

Calibrate the DVM as follows;

Note

Allow the DVM to warm up for 30 minutes before making any adjustments.

Steps a through d and steps k through m refer to the function and control section; steps e through j refer to the analog-to-digital converter section. The location of adjustment potentiometers on main circuit board (A1) of the DVM is shown in figure 4-1. Adjustment potentiometers which are a part of the analog-to-digital converter section (A2 and A3) are located in figure 4-2.

a. Connect a voltmeter to the +16-volt output, at +16 test point. Adjust (A1) R33 (figure 4-1) for +16.0 volts.

b. Connect the voltmeter to the -16-volt output at -16 test point. Adjust (A1) R36 for -16.0 volts.

c. Connect the voltmeter to the +5-volt output at +5 test point. Verify that it is +5.0 ±0.5 volts.

d. Connect the voltmeter to monitor the output of the scaling amplifier at J2-12. With the input jacks shorted, and with the DVM on the 1V range, adjust the ZERO control on the front panel for zero-volt output.

e. Connect the voltmeter to the following test points and verify the output voltages.

Analog Board (A2):

+18V	+18 ±3 volts
+30V	+30 ±5 volts
-18V	-18 ±3 volts
-30V	-30 ±5 volts

Digital Board (A3):

+5V	+5 ±1 volt
+4V	+4 ±1 volt

f. Connect a 1 megohm resistor in series with the DC input to the analog-to-digital converter section at J2-12. Connect a voltage standard to the DVM input jacks and apply 1.0000 volt. Note the DMV reading. Remove the 1 megohm resistor and reconnect the DC input line. Adjust current null potentiometer A2R3 for exactly the same reading as noted above.

g. Connect a voltage standard to the DVM input jacks. Apply +0.0010 volt, then -0.0010 volt to the DVM. Adjust zero calibrate potentiometer A2R32 on the analog-to-digital converter (figure 4-2) so that the readout obtained with both polarity inputs is balanced.

h. Adjust zero width potentiometer A2R21 on the analog-to-digital converter for a 0.0010 readout. Set the voltage standard output to 0.0000 and verify that the readout is 0.0000 ±1 digit.

i. Apply +1.5000 volts to the DVM. Adjust full scall calibrate potentiometer A2R26 on the analog-to-digital converter for a readout of +1.5000 volts.

j. Apply -1.500 volts to the DVM. Adjust negative polarity gain potentiometer A2R19 for a readout of -1.5000 volts ±1 digit.

k. Switch to the 10V range. Apply +15.000 volts to the DVM. Adjust potentiometer A1R2 (figure 4-1) for a readout of +15.000 volts ±1 digit.

l. Switch to the 100V range. Apply +150.00 volts to the DVM. Adjust potentiometer A1R4 for a readout of +150.00 volts ±1 digit.

m. Switch to the 1,000V range. Apply +1000.0 volts to the DVM. Adjust potentiometer A1R6 for a readout of +1000.0 volts ±1 digit.

n. Recheck the accuracy of the DVM in accordance with step 1 of table 4-2.

4-17. CALIBRATION OPTION. Proceed as follows:

Note

The DVM must be operating for a minimum of 3 hours before performing this calibration.

a. Apply +1.000 volt to the DVM with the voltage standard. Verify that the readout is +1.0000 volt ±3 digits.

b. Depress the CAL pushbutton. Adjust fine adjust potentiometer A1R41 (figure 4-1) to the center of its range.

c. Adjust coarse adjust potentiometer A1R42 for a readout that is within ±5 digits of +1.0000 volt.

d. Switch to the 1V range and observe the exact readout obtained from the voltage standard input of step a.

e. Switch back to CAL and adjust A1R41 for exactly the same readout.

4-18. ANALOG-TO-DIGITAL CONVERTER REMOVAL.

4-19. To remove the analog-to-digital converter circuit boards (A2 and A3) from the DVM, proceed as follows:

a. Remove the top and bottom panels of the DVM.

b. Disconnect J1 from digital circuit board (A3) and J2 from the analog circuit board (A2).

c. Remove four screws that secure the converter to the main circuit board. These are removed from the bottom of main circuit board (A1).

d. Remove the two screws retaining the display block (REM, m, V, etc. indicators) from the side of the converter.

e. Remove the converter circuit boards from the top of the DVM.

4-20. VOLTAGE DATA.

4-21. Voltages at transistor and IC components of the function and control section of the DVM are given in table 4-4. Voltage data at transistor and IC components of the analog-to-digital section is given in table 4-5. All measurements were taken with respect to chassis ground and with the signal and chassis grounds strapped together. Voltages were measured with a Model 3600

(with input leads shorted together.)

Table 4-4. Function and Control Section Voltage Data

TRANSISTOR	TYPE	NOMINAL EMITTER VOLTAGE	NOMINAL BASE VOLTAGE	NOMINAL COLLECTOR VOLTAGE
A1Q1	2N3053	+1[illegible]V	+1[illegible].7V	+2[illegible]V
A1Q2	2N3053	+0.1V	+8V	+9V
A1Q3	2N3054	+5V	+5.7V	+11V
A1Q4	2N3053	+5.7V (S:1,4)	+6.3V (G:3)	+11V (D:2)
A1Q5	LS3954	+0.5V +0.5V	0V 0V(G:6)	+8.3V +8.3V (D:5)
A1Q6	2N4390	0V	0.6V	+0.2V
A1Q7	2N4390	0V	0V	+75V
A1Q8	2N4390	0V	0V	+75V
A1Q9	2N4390	0V	0V	+75V
A1Q10	2N4390	0V	0V	+75V
A1Q11	MPS6521	-12.6V	-12.0V	+0.5V

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A[illegible]	+1[illegible]	+[illegible]	+[illegible]	[illegible]	-1[illegible]	[illegible]	+1[illegible]	-.6V		
A[illegible]	[illegible]	-[illegible]	-[illegible]	-[illegible]	[illegible]	-[illegible]	+[illegible]	+[illegible]	+[illegible]	+.0[illegible]
A[illegible]	+[illegible]	+[illegible]	+[illegible]	+[illegible]	[illegible]	+[illegible]	[illegible]	+[illegible]	+1[illegible]	+1[illegible]

Conditions of Measurement:

1. Input voltage is 115VAC.

2. Input shorted on 1V range.

Table 4-5. Analog-To-Digital Converter Section Voltage Data

		NOMINAL EMITTER VOLTAGE	NOMINAL BASE VOLTAGE	NOMINAL COLLECTOR VOLTAGE
[illegible]	[illegible]	25V	24.3V	1.2V
[illegible]	[illegible]	1.2V	0.7V	0V
[illegible]	[illegible]	0V	-.4V	-30
[illegible]	Not Used			
[illegible]	Not Used			
[illegible]	2N2919A	-0.4V	0V	10V
[illegible]	2N2919b	-0.4V	0V	10V
[illegible]	SE4020	-18.7V	-18	-0.4V
[illegible]	2N5138	10.7V	10V	0V
[illegible]	2N5138	17V	16.3V	-25V
[illegible]	2N5138	17V	16.3V	-0.4V
[illegible]	2N5138	10.7V	10V	0V
[illegible]	SE4020	-25.7V	-25.V	-0.4V
[illegible]	SE4020	0V	-0.4V	21V
[illegible]	2N5138	0V	-0.4V	-21V
[illegible]	SE4020	0V	0V	21V
[illegible]	2N5138	0V	0V	-21V
[illegible]	SE4020	-14.2V	-21V	21V
[illegible]	SE4020	-14.9V	-14.2V	21V
[illegible]	2N5138	21.8V	22.5V	+18V
[illegible]	2N5138	21.8V	22.5V	23.6V
[illegible]	2N5138	24.2V	23.6V	20V
[illegible]	2N5138	22.5V	24.2V	20V
[illegible]	2N5138	21.3V	20.6V	21V
[illegible]	SE4020	--	19.8V	21V
[illegible]	SE4020	--	20V	19.8
		(S)	(G)	(D)
[illegible]	2N5458	-21V	19.8V	30V
[illegible]	2N5138	+31.2	+30V	22V
		S)	(G)	(D)
[illegible]	2N5458	21.9V		31.2V
[illegible]	[illegible]	21.9V	21.3V	0.5V
[illegible]	[illegible]	19.8V	19.2V	0.6V
[illegible]	[illegible]	0	0.6V	0 to 30V
[illegible]	[illegible]	0	0.5V	19.2V
[illegible]	[illegible]	39.4V	38.8V	+31.2V
[illegible]	[illegible]	24.2V	24.8V	38.8V
[illegible]	[illegible]	24.2V	22.5V	31.2V
[illegible]	[illegible]	0	-0.6V	-33.4V
[illegible]	2N5138	-32.8V	-33.4V	-38.0V
[illegible]	2N5133	+31.2V	NC	+21.3V
[illegible]	Not Used			
A2Q41	SE4020	30.7V	0.3V	-0.2V
A2Q42	2N5138	0	-0.2V	-0.4 to -3.5V
A2Q43	2N5134	-0.4 to -[illegible]	0 to -3V	0

Table 4-[illegible]. Analog-To-Digital Converter Section Voltage Data (Cont)

TRANSISTOR	TYPE	NOMINAL EMITTER VOLTAGE	NOMINAL BASE VOLTAGE	NOMINAL COLLECTOR VOLTAGE
A2Q44	2N5138	0	0 to +1V	-2V to -7V
A2Q45	2N5133	0	-6V to 0	0 to 18V
A2Q46	2N5133	0	-6V to 0	0 to 18V
A2Q47	SE4020	0.7V	1.4V	5.8V
A2Q48	SE4020	0	0.7V	5.8V
A2Q49	2N5133	5.1V	5.8V	+30
A3Q1	SE4020	0	0 to 0.7V	0.2V to 70V
A3Q2	SE4020	0	0 to 0.7V	0.2V to 70V
A3Q3	SE4020	0	0 to 0.7V	0.2V to 70V
A3Q4	2N5134	1.4V	2V	1V to 8V
A3Q5	2N5134	0	0.7V	0V to 8V
A3Q6	2N5134	0	0.7V	0V to 5V
A3Q7	2N5134	0	0.7V	0V to 5V
A3Q8	2N5134	0	0.7V	0V to 5V
A3Q9	2N5135	0	0.7V	0V to 5V
A3Q10	2N5133	0	0.7V	0V to 30V
A3Q11	2N5134	0	0.7V	0V to 5V
A3Q12	2N5134	0	0.7V	0V to 5V
A3Q13	2N5134	0	0.7V	0V to 5V
A3Q14	2N5138	+.5V	+4.3V	0V to 5V
A3Q15	2N5133	NA	NA	NA
A3Q16	2N5141	0.7V	0V	0
A3Q17	2N5133	0	0.7V	0V
A3Q18	2N5136	.5V to 2V	0 to 1.4V	.8V

	PIN						
IC	3	4	5	6	9	10	11
A2IC1	-32V	-21V	-21V	-32V	-32V	-21V	0

Conditions of Measurement:

1. Input voltage is 115VAC
2. Input shorted on 1V range
3. Depends upon input voltage polarity, -3V for +1 VFS DC INPUT (J2-12).
4. With Module option, MODULE pushbutton depressed.

SECTION V

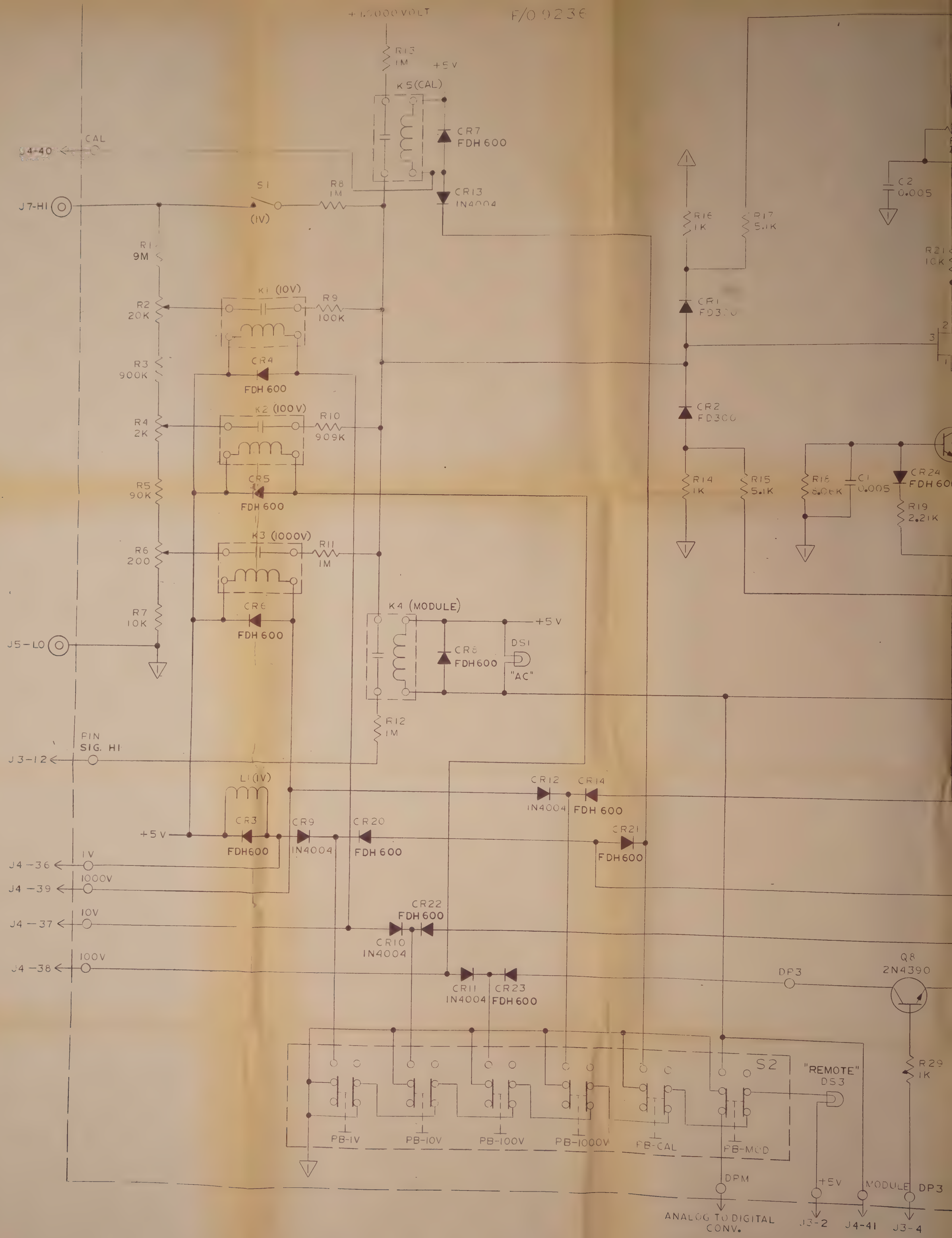
SCHEMATIC DIAGRAMS

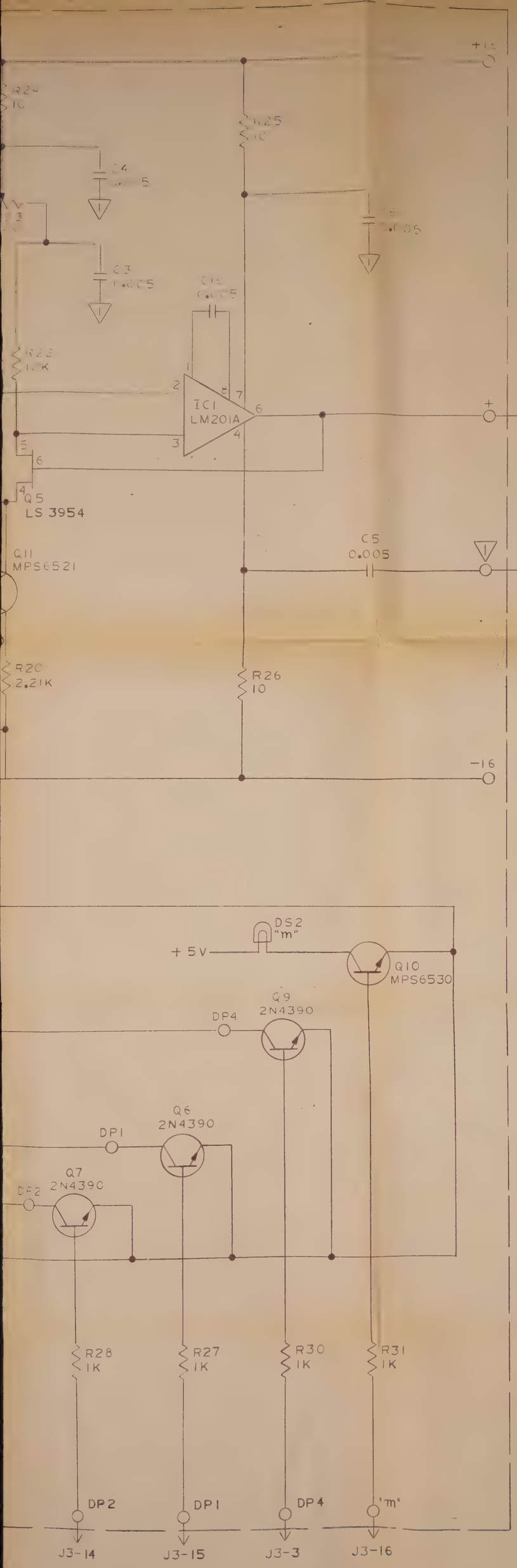
Figure 5-1. Model 3600 DC DVM, Function and Control (A1), Schematic Diagram

Figure 5-2. Model 3600 DC DVM, Power Supplies and Option Connectors (A1), Schematic Diagram

Figure 5-3. Model 3600 DC DVM, Analog Board (A2), Schematic Diagram

igure 5-4. Model 3600 DC DVM, Digital Board (A3), Schematic Diagram

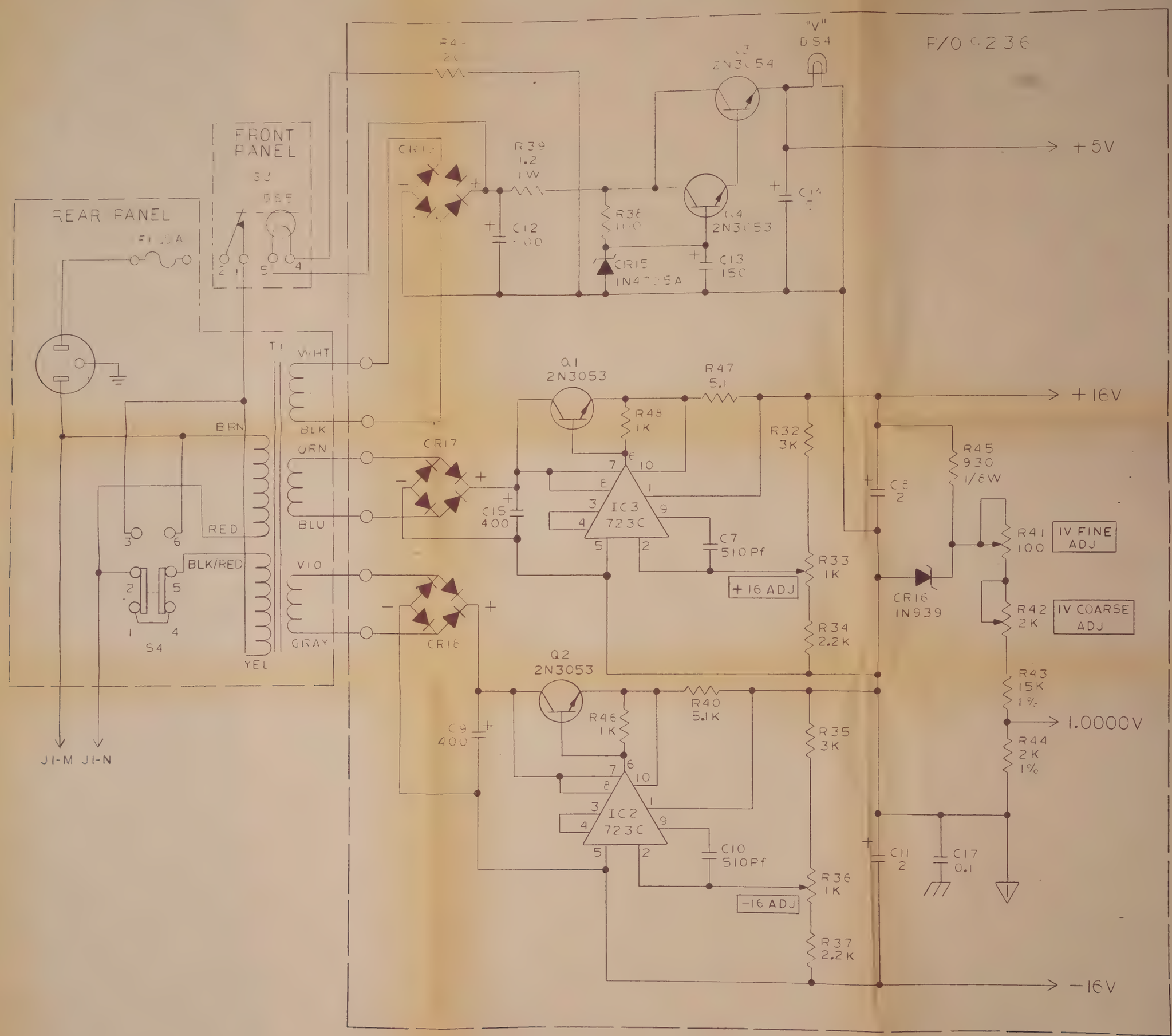

+12,000 VOLT
F/0 923E
R13
1M
+5V
K5 (CAL)
CR7
FDH 600
CR13
IN4004
CAL
J4-40
J7-HI
S1
(1V)
R8
1M
R1
9M
K1 (10V)
R9
100K
R2
20K
R3
900K
CR4
FDH 600
K2 (100V)
R10
909K
R4
2K
R5
90K
CR5
FDH 600
K3 (1000V)
R11
1M
R6
200
CR6
FDH 600
R7
10K
J5-LO
K4 (MODULE)
+5V
CR8
FDH 600
DS1
"AC"
R12
1M
PIN
SIG. HI
J3-12
L1 (1V)
CR3
FDH600
+5V
CR9
IN4004
CR20
FDH 600
CR12
IN4004
CR14
FDH 600
CR21
FDH 600
J4-36
1V
J4-39
1000V
J4-37
10V
J4-38
100V
CR22
FDH 600
CR10
IN4004
CR11
IN4004
CR23
FDH 600
DP3
Q8
2N4390
R29
1K
S2
"REMOTE"
DS3
PB-1V
PB-10V
PB-100V
PB-1000V
PB-CAL
PB-MOD
DPM
ANALOG TO DIGITAL CONV.
+5V
J3-2
MODULE
J4-41
DP3
J3-4
R16
1K
R17
5.1K
C2
0.005
R21
10K
CR1
FD300
CR2
FD300
R14
1K
R15
5.1K
R18
8.06K
C1
0.005
CR24
FDH 600
R19
2.21K



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   RESISTANCE VALUES ARE IN OHMS
   CAPACITANCE VALUES ARE IN MICROFARADS

Figure 5-1. Model 3600 DC DVM
Function and Control (A1),
Schematic Diagram



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   RESISTANCE VALUES ARE IN OHMS.
   CAPACITANCE VALUES ARE IN MICROFARADS.
2. ✱ INDICATES INPUT PROGRAM LINE.

Figure 5-2. Model 3600 DC [illegible]
Power Supplies [illegible]
[illegible]

PARTS LIST

PART NO: 3600
NOMENCLATURE: LIST OF SUB-ASSEMBLIES DIGITAL VO[illegible]

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
[illegible]		[illegible]	[illegible]			
[illegible]		[illegible]	[illegible]			
[illegible]		[illegible]	[illegible]			
[illegible]		[illegible]	[illegible]			

PARTS LIST

PART NO: 3600
NOMENCLATURE: DIGITAL VOLTMETER

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		

PARTS LIST

PART NO: 6043
NOMENCLATURE: DIGITAL PANEL METER

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		

PARTS LIST

PART NO: 6573
NOMENCLATURE: ANALOG PCBD ASSY

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
			CARBON FILM RESISTORS			
			Singer p/n 9621			
		6	100 K ohms, 1/4W, 5%, Singer p/n 9204			
		2	33 K ohms, 1/4W, 5%, Singer p/n 9210			
		4	22 K ohms, 1/4W, 5%, Singer p/n 9283			
			10 K ohms, 1/4W, 5%, Singer p/n 9281			
			5.1 K ohms, 1/4W, 5%, Singer p/n 9213			
		1	1.8 K ohms, 1/4W, 5%, Singer p/n 9[illegible]			
		1	10 ohms, 1/4W, 5%, Singer p/n 9280			
		3	10 megohms, 1/2W, 10%, Singer p/n 9259			
		1	4.7 megohms, 1/2W, 10%, Singer p/n 9263			
		1	3.3 megohms, 1/2W, 10%, Singer p/n 9262			
		1	2.7 megohms, 1/2W, 10%, Singer p/n 9213			
		1	2.2 megohms, 1/2W, 10%, Singer p/n 9258			
		4	1 megohm, 1/2W, 10%, Singer p/n 9260			
		2	470 K ohms, 1/2W, 5%, Singer p/n 2648			
		1	220 K ohms, 1/2W, 5%,			

PARTS LIST

PART NO: 6573
NOMENCLATURE: ANALOG PCBD ASSY

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
			CARBON FILM RESISTORS			
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	68 K ohms, 1/2W, 5%, Dinger p/n [illegible]	73445		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	1	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	330 ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] ohms, [illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], Dinger p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] megohms, 1/2W, 10%, Dinger p/n 8964	[illegible]		

PARTS LIST

MODEL: 3605

PART NO: 0573

NOMENCLATURE: ANALOG PCBD ASSY

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
	[illegible]		[illegible]			
[illegible]	[illegible]	*	[illegible] K ohms, [illegible], [illegible], Singer p/n 6622	[illegible]		
[illegible]	[illegible]	*	[illegible] K ohms, 1/8W, [illegible], Singer p/n 6623	[illegible]		
[illegible]	[illegible]	*	[illegible] K ohms, [illegible], [illegible], [illegible]	[illegible]		
			* [illegible] these items will be used as determined by Calif. [illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	1	6.6 K ohms, 1/4W, .1%, [illegible] ±10 PPM/°C, Singer [illegible]	[illegible]		
[illegible]	[illegible]	1	[illegible] K ohms, 1/4W, .1%, [illegible] ±[illegible] PPM/°C, Singer [illegible]	[illegible]		
[illegible]	[illegible]	1	[illegible] K ohms, 1/4W, [illegible], Singer p/n 6603	[illegible]		
[illegible]	[illegible]	1	[illegible] K ohms, [illegible], [illegible], [illegible]	[illegible]		
[illegible]	[illegible]	1	24.3 K ohms, 1/4W, 1%, [illegible] p/n 6602	[illegible]		

PARTS LIST

PART NO: 6573
NOMENCLATURE: ANALOG PCBD ASSY

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
			POTENTIOMETERS			
[illegible]		[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]		[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]		[illegible]	[illegible]		
			PLASTIC [illegible]			
[illegible]		[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
			[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible] +50%, [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible] p/n 9380	[illegible]		
[illegible]	[illegible]	[illegible]	0.22 uF, 35V, 20%, Bullet, Tantalum, Singer p/n 9577	[illegible]		
			[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

PARTS LIST

Page

PART NO: 6573
NOMENCLATURE: ANALOG PCBD ASSY

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
			FIXED CERAMIC CAPACITORS			
[illegible]	[illegible]	[illegible]	[illegible] pF, 1000V, 10%, [illegible]ralab DD-15[illegible]	[illegible]		
[illegible]	[illegible]		[illegible], [illegible]V, 10%, [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible]V, 10%, [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], Aerovox [illegible]	[illegible]		
[illegible]	[illegible]		[illegible], +[illegible] -[illegible], [illegible]	[illegible]		
	[illegible]		[illegible]			
[illegible]	[illegible]	[illegible]	[illegible] p/n 79[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]		[illegible]	[illegible]3		
1N41[illegible]	[illegible]		[illegible]	[illegible]		
1N756	15	1	6.2V Zener Singer p/n [illegible]			
[illegible]	[illegible]	[illegible]	[illegible]8, Singer p/n [illegible]	[illegible]		
[illegible]	[illegible]		Transistor (Selected per MS9[illegible]/9456)			

PARTS LIST

MODEL: 3600

PART NO: 6573

NOMENCLATURE: ANALOG PCBD ASSY

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
	[illegible]		[illegible]			
	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]istor, Singer [illegible]	[illegible]		
	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible], Singer [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
	[illegible]		INTEGRATED CIRCUITS			
[illegible]	[illegible]	[illegible]	[illegible], Singer [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]		[illegible]	[illegible]			
[illegible]		[illegible]	[illegible], Analog Board			
[illegible]		[illegible]	[illegible]			

PARTS LIST

PART NO: 6574
NOMENCLATURE: PARTS LIST DIGITAL PC BD. ASSY.

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
			CARBON FILM RESISTORS			
1-2-1[illegible]1M	41	1	1 megohm, [illegible] Singer p/[illegible]	[illegible]		
1-2-[illegible]390K	28	1	390 k ohms, [illegible] p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1-2-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1-[illegible]10K	[illegible]	[illegible]	[illegible]	[illegible]		
1-2-[illegible]1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
1-2-[illegible]1K	[illegible]	[illegible]	[illegible] 9277	[illegible]		

PARTS LIST

PART NO: 6574
NOMENCLATURE: PARTS LIST DIGITAL PC BD. ASSY.

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
[illegible]	[illegible]	[illegible]	[illegible] ohms, 1/2W, [illegible], Singer p/n 9283	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible], [illegible]	[illegible]		
			[illegible] CAPACITORS			
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible], [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible]	[illegible]		
			[illegible]			
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], "[illegible]", [illegible], [illegible], [illegible]	[illegible]		
			[illegible]			
[illegible]	[illegible]	[illegible]	[illegible], [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible]	[illegible]		
			[illegible] CAPACITORS			
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible], [illegible], Singer p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible], [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible] -[illegible], Singer p/n [illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible], [illegible], [illegible], [illegible], [illegible], [illegible]	[illegible]		

PARTS LIST

MODEL: 3600

PART NO: 4574
NOMENCLATURE: PARTS LIST DIGITAL PC BOARD.

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
			[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
			[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
			[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

PARTS LIST

PART NO: 6574
NOMENCLATURE: PARTS LIST DIGITAL PC BD. ASSY.

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		

PARTS LIST

PART NO:
NOMENCLATURE:

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
			[illegible]ITION RESISTOR			
			[illegible]			
			3 k ohms, 1/4W, 5%, Sin[illegible] p/n 9840			
			[illegible], 1/4, [illegible],			
			[illegible], 1/4, [illegible], Singer			
			[illegible], 1/4, [illegible], Singer			
			[illegible], 1/4, [illegible], Singer			
			[illegible], 1/4, [illegible], Singer			
			[illegible], 1/4, [illegible], Singer			
			[illegible], [illegible], [illegible], Singer			
			[illegible]			
			[illegible], 1/4, Singer			
			[illegible], 1/4, Singer			
			[illegible], 1/4, Singer			
			[illegible], 1/4, Singer			
			[illegible], 1/4, Singer			
			[illegible], 1/4W, Singer			

PARTS LIST

MODEL: 3600

PART NO: [illegible]

NOMENCLATURE: PARTS LIST P.C. BOARD ASSY.

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

PARTS LIST

MODEL: 3600

PART NO: 6579

NOMENCLATURE: PARTS LIST P.C. BOARD ASSY.

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		

PARTS LIST

MODEL:

PART NO: 6579

NOMENCLATURE: PARTS LIST P.C. BOARD

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		

PARTS LIST

PART NO: 6579

NOMENCLATURE: PARTS LIST I.C. BOARD ASSY.

PART NO.	REF DESIG	QTY	DESCRIPTION	FMC		

LIST OF MANUFACTURERS

FEDERAL MFR CODE	NAME
00656	Aerovox Corp. New Bedford, Mass. 02745
00779	AMP Inc. Harrisburg, Pa. 17105
01121	Allen Bradley Co. Milwaukee, Wis. 53204
01295	Texas Instruments Inc. Dallas, Texas 75231
02459	Grand Transformers Inc. Grand Haven, Mich. 49417.
02660	Amphenol Connector Broadview, Ill. 60153
02735	RCA Corp. Solid State Div. Somerville, N.J. 08876
03888	Pyrofilm Resistor Co. Inc. Whippany, N.J. 07981
03911	Clairex Corp. New York, N.Y. 10001
04713	Motorola Semiconductor Products Inc. Phoenix, Ariz. 85008
05397	Union Carbide Corp. Cleveland, Ohio 44101
05920	Wakefield Engineering Inc. Wakefield, Mass. 01880
06540	Amatom Electronic Hardware Div of Mite Corp. New Rochelle, N.Y. 10802
07263	Fairchild Mountain View, Calif. 94040
08806	General Electric Co. Miniature Lamp Dept. Cleveland, Ohio 44112
12040	National Semiconductor Corp. Danbury, Conn. 06810
12617	Hamlin Inc. Lake Mills, Wis. 53551
15786	Textron Inc. Belmont, Calif. 94002
18542	New Product Eng Inc. Wabash, Ind. 46992
19701	Electra/Midland Corp. Mineral Wells, Tex. 76067
27735	Fdyne Electronic Co. Fairfield, Conn. 06430
29505	Temple Industries Tecate, Calif. 92080

LIST OF MANUFACTURERS (Cont)

FEDERAL MFR CODE	NAME
37942	Mallory PR and Co. Inc. Indianapolis, Ind. 46206
53021	Sangamo Electric Co. Springfield, Ill. 62705
71279	Cambridge Thermionic Corp. Cambridge, Mass. 02138
71400	Bussman Mfg. St. Louis, Mo. 63017
71468	ITT Cannon Electric Inc. Los Angeles, Calif. 90031
71590	Centralab Div Globe Union Inc. Milwaukee, Wis. 53201
71744	Chicago Miniature Lamp Works Chicago, Ill. 60640
71785	Cinch Mfg Co. and Howard B. Jones Div Chicago, Ill. 60624
72259	Nytronics Inc. Pelham Manor, N.Y. 10803
72982	Erie Technological Products Inc. Erie, Pa. 16512
73138	Beckman Instruments Inc. Helipot Div Fullerton, Calif. 92634
73293	Hughes Aircraft Co. Torrance, Calif. 90509
73445	Amperex Electronics Corp. Hicksville, N.Y. 11801
74276	Signalite Inc. Neptune, N.J. 07753
75042	IRC Div of TRW Inc. Philadelphia, Pa. 19108
75915	Littelfuse Inc. Des Plaines, Ill. 60016
76493	Miller JW Company Compton, Calif. 90024
78189	Shakeproof Div of Illinois Tool Works Inc. Elgin, Ill. 60126
80031	MEPCO Inc. Div of Sessions Clock Co. Morristown, N.J. 07960
80131	Electronic Industries Assoc.

LIST OF MANUFACTURERS (Cont)

FEDERAL MFR CODE	NAME
80183	Sprague Products Co. North Adams, Mass.
80294	Bourns Inc. Riverside, Calif. 92507
81349	Military Specs
82068	Burnellnytronics Alpha, N.J. 08865
82389	Switchcraft Inc. Chicago, Ill. 60630
83330	Smith Herman H. Inc. Brooklyn, N.Y. 11207
84171	ARCO Electronics Inc. Great Neck, N.Y. 11022
84411	TRW Capacitor Div Ogallala, Nebr.
87034	Marcooak Industries Inc. Anaheim, Calif. 92803
95348	Gordos Corp Bloomfield, N.J. 07003
98291	Sealectro Corp. Mamaroneck, N.Y, 10544
95354	Methode Mfg. Corp. Rolling Meadows, Ill. 60008